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Proceedings of the Eighteenth LAMPF Users Group Meeting

Los Alamos National Laboratory
Los Alamos, New Mexico
October 29–30, 1984

Compiled by
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Los Alamos, New Mexico 87545

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PROCEEDINGS OF THE EIGHTEENTH LAMPF USERS GROUP MEETING

Compiled by

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ABSTRACT

The Eighteenth Annual LAMPF Users Group Meeting was held October 29-30, 1984, at the Clinton P. Anderson Meson Physics Facility. The program included a number of invited talks on various aspects of nuclear and particle physics as well as status reports on LAMPF and discussions of upgrade options. The LAMPF working groups met and discussed plans for the secondary beam lines, experimental programs, and computing facilities.

PROGRAM

EIGHTEENTH ANNUAL LAMPF USERS GROUP MEETING

Los Alamos National Laboratory — October 29-30, 1984

Chairman: Charles Glashausser, Rutgers University
Chairman-Elect: Robert Redwine, Massachusetts Institute of Technology

Monday, October 29 — **LAMPF Auditorium, Laboratory-Office Building (MPF-1, TA-53)**

MORNING SESSION

Charles Glashausser, Presiding

8:00 - 9:00 a.m.	Registration
9:00 - 9:30	Welcome — Gerald Garvey, Deputy Associate Director for Particle and Nuclear Physics, Los Alamos National Laboratory
9:30 - 10:00	LAMPF Operations Report — Donald Hagerman, Chief of Operations at LAMPF
10:00 - 10:30	COFFEE BREAK
10:30 - 11:30	Wolfram Weise (University of Regensburg) — *"What is the Pion?"*
11:30 - 12:15 p.m.	Eliazer Piasetzky (University of Tel Aviv) — *"Delta Dynamics in Nuclei"*
12:15 - 1:30	LUNCH — Buses to the Laboratory Support Complex Cafeteria

1:30 p.m. — **LAMPF Auditorium, Laboratory-Office Building (MPF-1, TA-53)**

AFTERNOON SESSION

Robert Redwine, Presiding

1:30 - 2:15 p.m.	Thomas Carey (Los Alamos) — *"Inclusive 500-MeV Nucleon Scattering and the EMC Effect"*
2:15 - 3:00	Vincent Yuan (Los Alamos) — *"Search for Parity Violation in $\vec{p}$-LH_2 $\vec{p}$-LD_2 Scattering at 800 MeV"*
3:00 - 3:30	COFFEE BREAK
3:30 - 4:00	Annual Users Group Report — Charles Glashausser, Chairman of Board of Directors
4:00 - 5:00	Terrence Goldman (Los Alamos) — *"Quarklei: Nuclear Physics from QCD!"*
6:30 p.m.	BANQUET AT RANCHO ENCANTADO (Tickets to this event *must be* purchased in advance.)

Tuesday, October 30 **LAMPF Auditorium, Laboratory-Office Building (MPF-1, TA-53)**

MORNING SESSION

8:30 - 9:15	Gerald Smith (Pennsylvania State University, Chairman of Brookhaven User Group) — *"Search for States Near N̄N Threshold"*
9:15 - 10:00	Gerald Miller (University of Washington) — *"Searching for Hidden Color Components of Nuclear Wave Functions with the Pion-Nucleus Double Charge Exchange Reaction"*
10:00 - 10:30	COFFEE BREAK
10:30 - 11:00	Henry A. Thiessen (Los Alamos) — *"LAMPF II"*

11:00 - 12:15 p.m.	WORKING GROUP MEETINGS	LAMPF Room
EPICS (Energetic Pion Channel and Spectrometers	William Cottingame (New Mexico State University), Chairman	Auditorium
LEP (Low-Energy Pion Channel)	Michael Leitch (Los Alamos), Chairman	D105
Neutrino Facilities	Thomas Romanowski (Ohio State University), Chairman	A234
NPL (Nucleon Physics Laboratory	Tarlochan Bhatia (Texas A&M University), Chairman	A114
Computer Facilities	James Amann (Los Alamos), Chairman	MP-14 Conference
SMC (Stopped Muon Channel)	Fesseha Mariam (Los Alamos), Chairman	A142

12:15 - 1:30 p.m.	LUNCH — Buses to the Laboratory Support Complex Cafeteria

1:30 - 3:30 p.m.	WORKING GROUP MEETINGS	LAMPF Room
HRS (High-Resolution Spectrometer)	Madgy Gazzaly (University of Minnesota), Chairman	Auditorium
μSR (Muon Spin Rotation)	Art Denison (University of Wyoming), Chairman	A228
Nuclear Chemistry	Yoshitaki Ohkubo (Los Alamos), Chairman	A114
P^3 (High-Energy Pion Channel)	Jon Engelage (UCLA), Chairman	A234
Solid-State Physics and Materials Science	Walt Sommer (Los Alamos), Chairman	D105

3:30 p.m. **LAMPF Auditorium, Laboratory-Office Building (MPF-1, TA-53)**

AFTERNOON SESSION

3:30 - 4:30	Robert Selden, Associate Director for Theoretical and Computational Physics, Los Alamos — *"Strategic Defense Research at Los Alamos"*
4:30 - 5:15	LAMPF Status Report — Louis Rosen, Director of LAMPF

STATUS OF LAMPF

L. ROSEN
LOS ALAMOS NATIONAL LABORATORY
LOS ALAMOS, NEW MEXICO 87545
OCTOBER 30, 1984

TALK TO LAMPF USERS GROUP

I. INTRODUCTION

WHEN THE AGENDA FOR THIS MEETING WAS ORGANIZED, IT APPEARED THAT I WOULD BE AT A MEETING OF THE US-USSR JCCFPM PRECISELY THE TWO DAYS OF THIS MEETING. I THEREFORE DECIDED THAT MY TALK THIS YEAR WOULD BE A REPORT ENTITLED "LAMPF - 15 YEARS LATER." EACH OF YOU SHOULD HAVE A COPY BUT, IF YOU DON'T, THERE ARE SOME AVAILABLE IN THE LOBBY. THIS REPORT, TOGETHER WITH WHAT HAS ALREADY BEEN SAID JUST ABOUT COVERS WHAT NEEDS TO BE SAID. HOWEVER, SINCE I AM ALREADY UP HERE.....,(FIG. 1). WE CAN ALL BE PROUD OF THE FACT THAT WE NOT ONLY ACCOMPLISHED WHAT WE PROMISED, MANY YEARS AGO, BUT QUITE A BIT MORE. I HAVE SHARED, WITH MOST OF YOU, THE RECENT COMMENTS MADE BY SECRETARY HODEL, BUT THEY ARE WORTH REPEATING. HE SAID, AND I QUOTE, "I AM PROUD OF THE DEPARTMENT'S BASIC RESEARCH PROGRAMS AND THE EXCELLENT ACCELERATOR AND REACTOR FACILITIES WHICH MAKE THESE BASIC RESEARCH PROGRAMS POSSIBLE. AS YOUR REPORT, LAMPF - FIFTEEN YEARS LATER SO ABLY DESCRIBES, THE CLINTON P. ANDERSON MESON PHYSICS FACILITY (LAMPF) HAS COMPILED A DISTINGUISHED RECORD OF ACCOMPLISHMENT AND SERVICE TO THE NATION.

STATUS OF LAMPF

I A NOTE FROM SECRETARY HODEL

II WELCOME TO GERRY GARVEY

III LAMPF II - HOW DO WE GET THERE FROM HERE?

IV BUDGETARY OUTLOOK

V ON THE LIGHTER SIDE:
LAMPF PAYS FOR ITSELF AGAIN!

Figure 1

PLEASE EXTEND MY GREETINGS AND BEST WISHES TO THE MANY PEOPLE WHO HAVE CONTRIBUTED TO LAMPF'S PRODUCTIVE PAST AND BRIGHT FUTURE." THAT MEANS YOU.

SO WHAT HAS THE SECRETARY DONE FOR US LATELY?

AS FAR AS I CAN TELL, HE HAS BEEN VERY SUPPORTIVE OF LAMPF, AND WE, FOR OUR PART, HAVE NOT LET HIM DOWN. FOR THIS FISCAL YEAR HE HAS APPROVED $1 M FOR A NEW LAB-OFFICE BUILDING. THIS WILL GIVE US SOME RELIEF. WE WILL ALSO TRY TO IMPROVE THE ENVIRONMENT IN OUR MAIN LOBBY AND THE CAFETERIA. TO ACCOMPLISH THAT WE HAVE ENGAGED THE SERVICES OF THE BEST INTERIOR DECORATOR WEST OF THE MISSISSIPPI. IN CASE JACK ANDERSON IS LISTENING, THE AFOREMENTIONED INTERIOR DECORATOR IS PROVIDING HER SERVICES FREE OF CHARGE.

II. WELCOME TO GERRY GARVEY

AS BY NOW YOU KNOW, IT IS OUR GOOD FORTUNE THAT GERRY GARVEY HAS DECIDED TO JOIN LOS ALAMOS NATIONAL LABORATORY. HIS TITLE IS DADPNP AND HE

WILL CONTRIBUTE TO NATIONAL GOALS IN MANY WAYS. AMONG OTHER THINGS HIS PRESENCE HERE WILL ASSURE CONTINUITY OF LEADERSHIP AT LAMPF FAR INTO THE FUTURE. THIS IS EXTREMELY IMPORTANT, IN VIEW OF OUR ASPIRATIONS TOWARDS LAMPF II. IT WILL ALSO AVOID THE TRAUMA TO IN-HOUSE STAFF AND LAMPF USERS WHICH AN ABRUPT CHANGE IN LEADERSHIP COULD CONCEIVABLY ENGENDER.

III. SCENARIO FOR ACHIEVING LAMPF II

LAMPF II ACTIVITIES ARE PROCEEDING AT A GOOD PACE. DURING FY85, APPROXIMATELY $2.5M WILL BE ALLOCATED TO THIS INITIATIVE, MOSTLY AS ISRD FUNDING. IT IS OUR GOAL THAT BY THE END OF THIS CALENDAR YEAR A PRELIMINARY PROPOSAL WILL BE AVAILABLE. TO ASSIST US IN THIS TASK WE HAVE ENGAGED THE SERVICES OF SCIENCE APPLICATIONS INTERNATIONAL (SAI). THAT EFFORT IS BEING COORDINATED AND OVERSEEN BY PAUL REARDON WHO REPORTS TO ARCH THIESSEN. THE MOST IMPORTANT PART OF THE PROPOSAL, THE SCIENTIFIC MOTIVATION, WILL BE IN EXCELLENT SHAPE. THE ACCELERATOR DESIGN AND CIVIL ENGINEERING WILL INDICATE THE MAJOR OPTIONS THAT WILL BE CONSIDERED AND WILL IDENTIFY THE COSTS ASSOCIATED WITH THE MOST CONSERVATIVE OPTIONS.

SEVERAL MONTHS AGO A NUMBER OF US ATTENDED THE HEIDELBERG CONFERENCE ON PARTICLES AND NUCLEI. THERE WERE ABOUT 600 ATTENDEES. THERE SEEMED TO BE A VERY STRONG CONCENSUS THAT THE NEXT STAGE IN THE EVOLUTION OF NUCLEAR SCIENCE REQUIRES A FACILITY GENERATING HIGH INTENSITY PROTON BEAMS OF ENERGY IN THE TENS OF GeV. SUCH FACILITIES ARE BEING ACTIVELY PLANNED IN CANADA, GERMANY, SWITZERLAND, USSR, AND JAPAN AS WELL AS IN THIS COUNTRY.

WE ARE MOVING AHEAD WITH LAMPF II AS FAST AS LEGAL, BUDGETARY, AND MOST IMPORTANTLY, PERSONNEL CONSTRAINTS WILL PERMIT.

IT IS, OF COURSE, ESSENTIAL THAT WE MAINTAIN OPERATION OF LAMPF AS EFFECTIVELY AS POSSIBLE AND AS LONG AS FEASIBLE. WE ARE FOCUSING ON A SCENARIO, SUBJECT TO DOE CONCURRENCE, THAT ASSUMES CONTINUING MAJOR IM-

PROVEMENT OF LAMPF FOR THE NEXT THREE YEARS, FOLLOWED BY THREE YEARS IN WHICH WE CONCENTRATE ON COMPLETING THE BEST EXPERIMENTS EVEN AS WE START CONSTRUCTING LAMPF II. FOLLOWING THESE SIX YEARS OF INTENSE OPERATION AND MASSIVE DATA ACCUMULATION WE WOULD PREPARE TO TERMINATE LAMPF OPERATION, EXCEPT WNR/PSR, WHILE WE COMPLETE LAMPF II AND DEPLOY THE FIRST ROUND OF EXPERIMENTS.

WE HAVE ALREADY STARTED TO DIVERT INCREASING RESOURCES TO LAMPF II ACTIVITIES. THIS, ADDED TO THE REQUIREMENTS OF OUR THREE-YEAR IMPROVEMENT PROGRAM, MEANS LESS IN-HOUSE SUPPORT FOR LAMPF USERS AND PERHAPS SOMEWHAT LOWER BEAM AVAILABILITY. BUT EVERY EFFORT WILL BE MADE TO MAINTAIN A STRONG, EFFICIENT, AND COST-EFFECTIVE OPERATION.

THE QUESTION WILL NOW INCREASINGLY ARISE AS TO WHICH CHANNEL OR CHANNELS MIGHT BE SHUT DOWN. I WANT TO ALERT YOU TO THE FACT THAT UNLESS WE SEE AN EXCEPTIONALLY STRONG NUCLEAR PHYSICS PROGRAM WHICH REQUIRES THE BIOMEDICAL CHANNEL, THAT CHANNEL WILL BE CLOSED DOWN VERY SOON. THIS WILL RELEASE LIMITED BUT HIGH QUALITY RESOURCES FOR LAMPF II AND FOR THE LAMPF IMPROVEMENT PROGRAM.

AS YOU KNOW THERE IS STRONG PRESSURE TO IMPROVE CAPABILITIES OF THE FACILITY IN MANY DIRECTIONS. PROPOSALS INCLUDE THE FOLLOWING:

<u>LAMPF IMPROVEMENTS PLANNED</u>

I BEAM SEPARATOR AND SPIN ROTATOR

II P - BUNCHER

LAMPF IMPROVEMENTS UNDERWAY

I REBUILD S. Y.

II HIGH INTENSITY H^- SOURCE, INJECTOR & BEAM TRANSPORT

III REBUILD A-6

IV HRS SHIELDING

V LAB-OFFICE BUILDING

VI TOFI

LAMPF IMPROVEMENTS UNDER DISCUSSION

I HIGH INTENSITY POL. ION SOURCE

II IMPROVED π^0 SPEC.

III LOW - RES. PROTON SPEC.

IV $\vec{N}$, $\vec{P}$ & $\vec{P}$, $\vec{N}$ FAC.

V DECAY IN-FLIGHT NEUTRINO FAC.

VI CRYSTAL BOX II

VII ATOMIC PHYSICS FAC.

DECISIONS HAVE ALREADY BEEN TAKEN TO INSTALL A BUNCHER AND TO BUILD A GOOD PARTICLE SEPARATOR AND BEAM ROTATOR. NOT ALL OF THE DESIRED IMPROVEMENTS CAN BE ACCOMPLISHED DURING THE NEXT THREE YEARS, BUT I THINK MOST OF THEM CAN. ADDITIONAL CAPITAL EQUIPMENT FUNDS WILL BE NECESSARY BUT THAT IS NEGOTIABLE.

IV. BUDGETARY OUTLOOK

OUR FY84 BUDGET PERMITTED US TO ACCOMPLISH ALL OF OUR MAJOR OBJECTIVES. BECAUSE OF LOWER THAN ANTICIPATED POWER COSTS, DUE TO THE AVAILABILITY OF MORE HYDROELECTRIC POWER THAN IS USUALLY THE CASE, WE WERE ABLE TO RUN SUBSTANTIALLY MORE HOURS THAN ORIGINALLY SCHEDULED. THIS HELPED TO MAKE FY84 A BANNER YEAR.

OUR GOALS FOR FY85 ARE EVEN MORE AMBITIOUS THAN FOR FY84. WE MUST COMPLETE, THIS CALENDAR YEAR, A PRE-TITLE ONE PROPOSAL FOR LAMPF II AND THEN AUGMENT OUR EFFORTS TOWARDS A FINAL PROPOSAL AND THE PROTOTYPING OF THE MAJOR NEW COMPONENTS OF THE FACILITY. WE FACE, DURING THE NEXT SIX MONTHS, AN ENORMOUS TASK IN REBUILDING THE SWITCHYARD TO MAKE POSSIBLE INJECTION INTO PSR, COMPLETING THE DEVELOPMENT AND INSTALLATION OF A HIGH INTENSITY H^- ION SOURCE, INJECTOR AND BEAM TRANSPORT SYSTEM, AGAIN FOR PSR, AND COMPLETELY REBUILDING THE BEAM STOP AREA, LONG OVERDUE. IN ADDITION, WE HOPE TO BRING INTO OPERATION TOFI, A MASSIVE DETECTOR SHIELD AT HRS, IMPROVEMENTS IN THE CLAM SHELL SPECTROMETER, INITIATION OF A NUMBER OF OTHER IMPROVEMENTS AND, OF COURSE, A LARGE EXPERIMENTAL PROGRAM BASED ON 2850 PRODUCTION HOURS IN FY85. I ESTIMATE THE ODDS AT 7 TO 5 IN FAVOR OF SUCCESSFUL COMPLETION OF OUR FY85 PROGRAM, WITHIN OUR BUDGET. HOWEVER, IT WILL REQUIRE THAT WE TAKE IN OUR BELT ANOTHER NOTCH, ROLL UP OUR SLEEVES ANOTHER INCH, AND WORK AT NEAR MAXIMUM EFFICIENCY.

NOTWITHSTANDING IMMEDIATE DEMANDS ON OUR TIME AND RESOURCES, LAMPF II GOES FORWARD. ARCH THEISSEN IS SPEARHEADING THE TECHNICAL EFFORT. HE HAS DEVELOPED A WORK BREAKDOWN OF ACTIVITIES WHICH MUST BE ADDRESSED DURING THE NEXT TWO YEARS. I HOPE THAT AT LEAST SOME OF YOU WILL VIGOROUSLY PARTICIPATE IN SOME OF THESE DEVELOPMENTS EITHER HERE OR AT YOUR HOME INSTITUTIONS.

FY86 OUTLOOK. ANYBODY ELSE UP THERE? YOU DON'T REALIZE HOW BAD THINGS CAN BE IN SCIENCE UNTIL YOU VISIT A COUNTRY LIKE YUGOSLAVIA.

V. ON THE LIGHTER SIDE - LAMPF PAYS FOR ITSELF AGAIN

ABOUT A YEAR AGO THE NEWS MEDIA CARRIED AN INTERESTING STORY. A TRUCKLOAD OF STRUCTURAL STEEL FROM MEXICO TRIGGERED A RADIATION ALARM WHEN IT GOT LOST AT LOS ALAMOS. ENSUING INVESTIGATION BROUGHT TO LIGHT THAT A COBALT SOURCE HAD BEEN SCRAPPED AND PARTS OF IT HAD FOUND ITS WAY INTO STEEL FOUNDRIES RESULTING IN MANY TRUCKLOADS OF CONTAMINATED STEEL. THE COST OF FINDING AND REPLACING THIS STEEL WAS QUITE HIGH. HOWEVER, HAD THIS PROBLEM GONE UNDETECTED FOR SEVERAL MORE YEARS THE COST OF FINDING AND REPLACING CONTAMINATED STEEL COULD HAVE BEEN RATHER ENORMOUS.

AND NOW, AS PAUL HARVEY WOULD SAY, "THE REST OF THE STORY."

WHEN LAMPF STARTED OPERATION I HAD RECURRING NIGHTMARES OF SOMEBODY PURPOSEFULLY OR ACCIDENTALLY REMOVING CONTAMINATED MATERIALS FROM LAMPF AND CAUSING LOW-LEVEL, BUT VERY ANNOYING CONTAMINATION IN THE TOWNSITE OR EVEN IN MORE REMOTE LOCATIONS. HEALTH HAZARDS WOULD BE MINIMAL BUT EMBARRASSMENT AND CLEAN-UP COSTS COULD BE SUBSTANTIAL. SO WHAT TO DO?

AT THAT TIME TOM PUTNAM WAS OUR SAFETY OFFICER AND LAMPF WAS STARTING UP. WE CONSIDERED THE QUESTION HOW WE MIGHT AVOID THE REMOVAL OF RADIOACTIVE MATERIALS FROM THE LAMPF SITE WITH A HIGH LEVEL OF CERTAINTY. THE OBVIOUS SOLUTION CAME TO MIND. EVEN THOUGH FUNDS WERE IN VERY

SHORT SUPPLY THAT YEAR I MADE AVAILABLE TO TOM PUTNAM ABOUT $100K TO DEVELOP AND INSTALL AN AUTOMATIC RADIATION ALARM SYSTEM UNDER THE HIGHWAY AT THE ENTRANCE TO LAMPF. OUR HEALTH AND SAFETY PEOPLE DID THE DESIGN AND DEVELOPMENT. IT WORKS BEAUTIFULLY AND I HAVE NOT HAD ANY TROUBLE SLEEPING EVER SINCE.

IT IS THIS ALARM SYSTEM WHICH DETECTED THE RADIOACTIVE STEEL FROM MEXICO AND BY SO DOING PROBABLY BECAME ONE OF THE MOST COST EFFECTIVE INVESTMENTS EVER MADE ANYWHERE ANYTIME. I PREDICT THAT IN DUE TIME, SUCH DETECTORS WILL BECOME COMMONPLACE THROUGHOUT THE WORLD.

Operations Report

Donald C. Hagerman

During FY 1984 LAMPF provided 3846 hours of one or two proton beams on target for research; this amount of production time is about 25% higher than that of recent years and near the all-time record for the facility. This level of production was made possible by favorable electrical costs resulting from heavy snowfall in Colorado and by an ambitious production schedule. Routine operation of average H+ currents as high as 950 μA was enjoyed; as required, peak H+ currents of 13 mA were used and significant experience at 10 1/2% duty factor was gained. The accelerator tune was quite reproducible over several months of operation; thus major tuneups were required only after lengthy shutdowns.

Cycle 41 (June-October 1984) displayed a somewhat disconcerting mixture of extremely good and extremely bad operation. The bad operation was due to a mixture of administrative and technical problems. The administrative problems included a lack of properly trained personnel and overly ambitious scheduling. The technical problems included rf-window problems, presumably related to high-duty-factor operation, failure of the A-6 window after many hours of beam exposure, water leaks on LEP and at A-5, and a catastrophic vacuum failure at P3. In spite of these difficulties and with the aid of a 3-week cycle extension, basically all scheduled experiments received their expected beam time.

In the experimental area, a major rebuilding of the target cells has been underway for the past two years. Cell A-2 was rebuilt during 1983, Cell A-1 during 1984, and A-6 will be rebuilt by spring 1985. Each of these rebuilding jobs had as goals improving reliability for high-current operation, easier routine maintenance, and adding where required new capabilities. Each rebuilding has required solution of a variety of demanding engineering and technical problems. The engineering problems include heat transfer, stress analysis, and heat generation due to nuclear reaction products; the technical problems come from the need to do nearly all installation work using remote handling techniques. It was gratifying to observe the improved performance of cells A-1 and A-2 during our recent high-current operation; similar improved results are expected after the A-6 work is completed.

The growing importance of polarized targets in the experimental program has demanded increased support and equipment from LAMPF. With the availability of additional personnel and new equipment in process of construction, it is expected that LAMPF can provide two separate polarized targets in the required configuration per year. The major emphasis is on proton targets, but eventually deuteron capabilities will be available. During the summer of 1984, this goal was surpassed, thanks to a large collaborative effort. As a result, three polarized targets were successfully operated simultaneously.

Other, relatively small-scale experimental area improvements include the new Clamshell Spectrometer used at LEP, partial support of the Time-of-Flight-Isochronous Spectrometer (TOFI), under construction for the nuclear chemistry program, partial support of the Line E neutrino facility, and further effort on particle separators.

The accelerator in many ways is a mature instrument but continues to receive attention in order to provide for new needs of the users, to replace obsolete equipment, or to improve overall facility performance.

The need for increased duty factor is becoming more urgent as the number of time-shared users increases and will receive continuing effort; at present 9% operation is routine, partial success has been achieved at 10 1/2%, and major equipment limitations appear at 12% duty factor. The replacement of the obsolete control computer has been under way for several years. It was quite gratifying to experience on-line trials for accelerator operation late last summer. Performance speed was slower than desired but should be amenable to speedup; further programming effort is needed. Some tune-up work will be done next spring using the new computer and the required control of the facility should be possible in one to two years.

Work has started on a buncher-chopper scheme for the P- source which, by the summer of 1986, should provide 100 nsec spacing between microscopic beam pulses with less than a factor of two reduction in average current. This development will significantly increase the opportunities for experiments using the polarized neutron beam while we continue to use the present polarized proton source. The only loss in flexibility due to the advent of the Proton Storage Ring (PSR) is the lack of a chopped (1-μsec spacing) low-intensity beam in Area A. This beam has been quite useful in particle identification and detector development studies; it will be restored in another year or two.

The larger scale improvement projects of a new polarized-ion source and a major upgrade of the Nucleon Physics Laboratory remain under consideration; we expect to reach a conclusion about one or both projects within the next few months. Louis Rosen has determined that improvement projects such as these must satisfy a six-year plan for the facility; this plan requires that significant improvement projects be completed within three years (FY85-87), maximum exploitation is to occur during the following three years (FY88-90), and finally we shall shut down the LAMPF experimental area for the installation of LAMPF II in FY1991. This implies that for the polarized-source change to occur, significant progress in the development of the optically-pumped Polarized Source must occur in the next few months and that LAMPF management must be convinced that adequate support of polarized-beam users will be provided for the next six years.* The upgrade of NPL requires further study before a decision can be reached.

Completion of the Proton Storage Ring Project (PSR) is expected during April 1985. During the six-month shutdown, which started October 22, 1984, LAMPF must reconfigure the low-energy transport system which connects the three injectors to the first tank of the linac and rebuild most of the beam switchyard at the end of the accelerator. These changes are necessary so that the required high-intensity H^- beam can be delivered to PSR. Almost all of the components are in hand for these projects, including nearly 60 magnets fabricated under the direction of MP-8; removal of old components and initial installation work proceeded very rapidly in the first few weeks of the shutdown. About a year ago, MP-11 started work on replacing the old H^- injector complex; initial tests of the new injector display the required H^- beam and adequate control of the x-ray background. MP-13 is primarily involved in the reconstruction of the switchyard while MP-1 and MP-2 pro-

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*Due to size limitations, further consideration of the Atomic Beam Polarized Source was dropped a few months ago.

vide the effort for many of the necessary control-system and wiring-plant changes.

The PSR has always been designed so that with minor exceptions, its operation will be transparent to the present LAMPF experimental program. An example of a typical distribution of pulses is listed below. Different pulse distributions of course are possible. The choice for a particular operating period will be made by Laboratory management with the aid of the Program Advisory Committee.

LAMPF Operating with PSR
(Dual-energy mode)

Facility	PPS	Duty Factor (%)
Area A	70	6.1
B, EPB, HRS	35	3.1
PSR	12	1.0
Line E	3	0.3
Total	120	10.5

This table clearly demonstrates the importance of increased duty factor to all users

We expect LAMPF to be back in full operation by April 22, 1985 after an extended turn-on period for testing of PSR modifications. This turn-on period will start in early March with testing of the low-energy transport system. Operation of the facility (assuming no major budget or technical problems) will continue through late fall of 1985. Production cycles will be 6 to 8 weeks long with 7- to 10-day breaks between cycles.

WHAT IS THE PION ?

Wolfram Weise
Institute of Theoretical Physics
University of Regensburg, Germany

ABSTRACT

Recent developments in understanding the very special properties of the pion are reviewed. We discuss its dual nature as a Goldstone Boson related to Chiral Symmetry Breaking on one hand, and as a bound quark-antiquark pair on the other hand. We point out open problems in reconciling the experimental facts about the pion size and decay with its well established role as a generator of the long range nuclear force.

INTRODUCTION

Half a century ago Yukawa published his pioneering work [1] "On the interaction of Elementary Particles". Over the years, his meson exchange picture has developed into a highly successful phenomenology of the nuclear force. The pion plays an outstanding role in this development. It is well established as the generator of the long range nucleon-nucleon potential. Its Compton wavelength $\lambda_\pi = \hbar/m_\pi c = 1.4$ fm determines the length scale of nuclear physics.

Another important decay channel is $\pi^0 \to 2\gamma$. The empirical decay width of 8 eV is close to the PCAC prediction[11)]

$$\Gamma(\pi^0 \to 2\gamma) = \frac{\alpha^2 m_\pi^3}{64 \pi^3 f_\pi^2} \tag{2}$$

(with α = 1/137).

b) Pion Form Factor

The pion charge radius $\langle r_\pi^2 \rangle^{1/2}$ is deduced from the form factor measured by scattering high energy pions from the electrons of a liquid hydrogen target. The result for the pion form factor[12)] at spacelike q^2 is shown in Fig. 1.

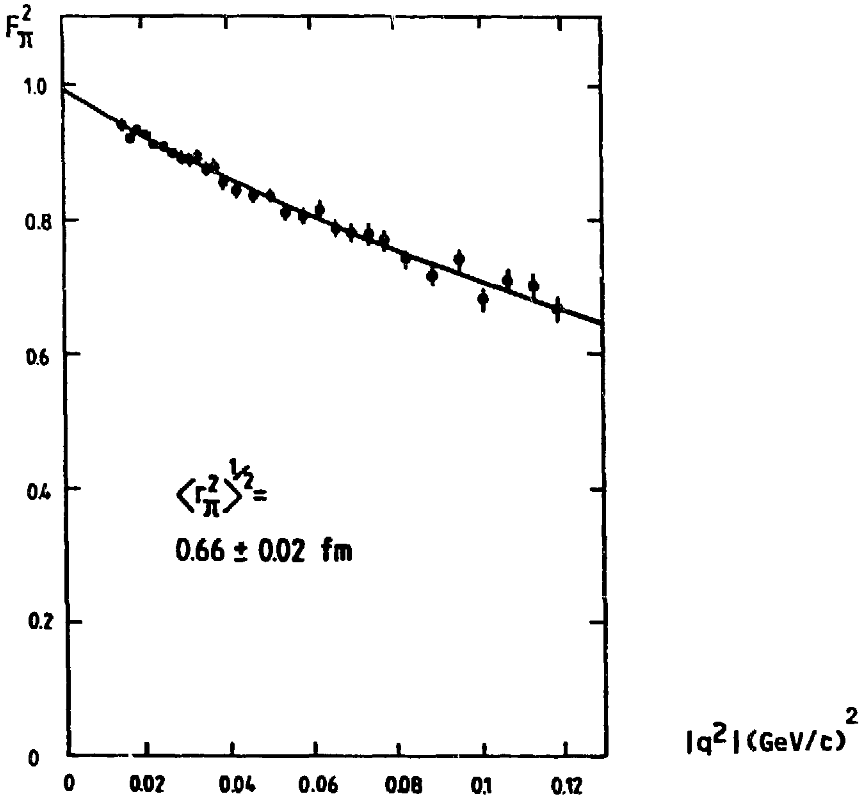

FIGURE 1
Squared pion charge form factor for spacelike q^2 as obtained in ref. 12. The pion r.m.s. charge radius $\langle r_\pi^2 \rangle^{1/2}$ is indicated in the figure.

The measurements of the pion form factor in the region of timelike q^2 (see Fig. 2 and ref. 13) exhibit very clearly the dominance of the ρ meson resonance at $q^2 = m_\rho^2 \simeq 0.59\ \mathrm{GeV}^2$. This means that a large part of the pion charge radius is actually related to the $\pi^+\pi^-$-cloud surrounding the pion as seen by the photon, rather than the intrinsic charge distribution of the pion core itself. In fact, the naive ρ meson dominance model gives

$$F_\pi(q^2) = \frac{F_\pi(0)}{1 - q^2/m_\rho^2} , \tag{3}$$

and a corresponding mean square radius $\langle r_\pi^2 \rangle = 6/m_\rho^2 = 0.38\ \mathrm{fm}^2$. This is already a good part of the empirical

$$\langle r_\pi^2 \rangle \simeq 0.44\ \mathrm{fm}^2.$$

This picture may be too simple, but it indicates that the size of the pion core, i.e. the radius relevant for the strong interactions of the pion, may be much smaller than its charge radius[14).

c) Pion Structure Function

So far we have discussed data obtained at low q^2. At high q^2 ($|q^2| > 25\ \mathrm{GeV}^2$) one expects that the quark-antiquark valence structure of the pion reveals itself more directly. This is explored by the Drell-Yan process where the antiquark of a high energy pion annihilates with a quark from a target nucleon to form a muon pair which is then analysed. Using existing information about the nucleon structure function, one can deduce the structure function of the pion. The results are summarized in terms of the amplitude $\bar{F}_\pi(x)$ which is a combination of structure functions for valence and sea quarks; here x is the fractional momentum carried by a quark in the pion (see Fig. 3).

The data at large x are understood entirely in terms of the valence quark-antiquark pair in the pion. At small x there is evidence for a more

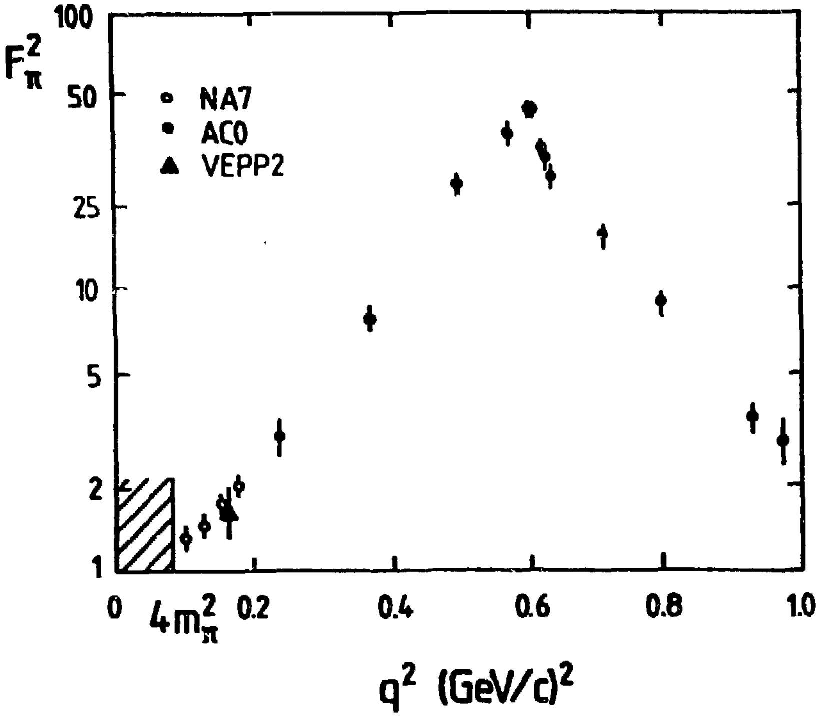

FIGURE 2
Squared pion form fac
in the timelike regio
(taken from ref. 13).

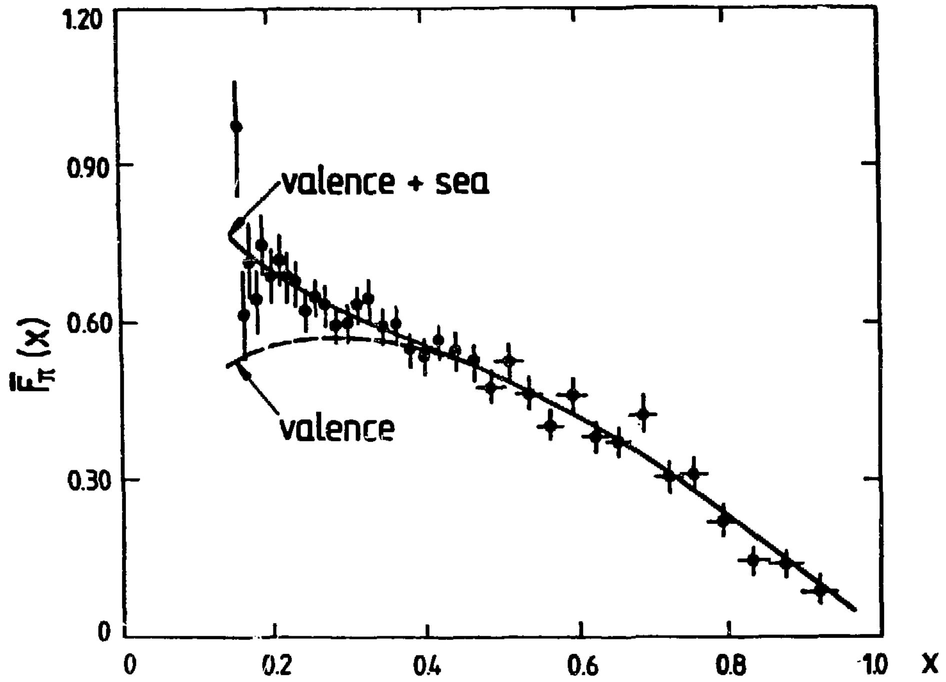

FIGURE 3
Pion structure function obtained from an analysis of the Drell-Yan process with 200 GeV incident pions. The dashed curve is the pure valence quark structure function, the solid curve represents the valence plus sea structure function (taken from ref. 15).

complex structure as represented by the "sea" component. Clearly, it would be very interesting to have data below $x \leq 0.2$.

MODELS OF THE PION

a) Constraints on Pion Size and Wave Function Components

We summarize briefly the approach developed by Brodsky and Lepage[16]. Their analysis is based on the assertion that the content of the pion wave function[+)] is much richer than that implied by a single bound $q\bar{q}$ pair:

$$|\pi\rangle = \sqrt{Z}\,|q\bar{q}\rangle + a\,|q\bar{q} + \text{gluons}\rangle + b\,|qq\bar{q}\bar{q}\rangle + \ldots \qquad (4)$$

with

$$Z + a^2 + b^2 + \ldots = 1.$$

Consider now the pion decay constant f_π. Current algebra requires that f_π does not depend explicitly on the pion mass m_π. Hence for dimensional reasons it must then be inversely proportional to the r.m.s. radius $R_\pi \equiv \langle r^2\rangle_\pi^{1/2}$. Furthermore, it measures the amplitude of the single $q\bar{q}$ component in the pion wave function, eq. (4):

$$f_\pi \simeq 0.4\,\frac{\sqrt{Z}}{R_\pi} \qquad (5)$$

where the constant multiplying $\sqrt{Z}/R_\pi$ is of purely geometric origin. On the other hand, the $\pi^0 \to 2\gamma$ amplitude is proportional to $\sqrt{Z}\cdot R_\pi$. From a combined analysis of both decays it is found that $Z \lesssim 1/4$ and $R_\pi \lesssim 0.4$ fm. Hence Brodsky et al. conclude that the probability of finding a single $q\bar{q}$-component

+) The Brodsky et al. analysis is actually carried out in the infinite momentum frame. We simplify the presentation here somewhat, keeping however the basic physical content.

in the pion is strongly reduced, while at the same time the hadronic pion radius is indeed considerably smaller than the empirical charge radius.

These findings cannot be understood in descriptions which identify the pion with a single $q\bar{q}$ pair in the 1s orbit of a bag or confining potential. In addition, the low pion mass does not arise in a natural way in such models.

b) The Pion as a Collective State

A picture completely different from the single bound $q\bar{q}$ pair is that of the pion as a collective $q\bar{q}$-excitation of the non-perturbative QCD vacuum. This makes the pion very special as compared to all other mesons. The notions developed in this context have a far-reaching analogy with low-energy collective modes in strongly interacting many-body systems. In that sense, the pion is analogous to a low-lying, highly collective particle-hole state, the particle and hole corresponding to the quark and antiquark, respectively, whereas the heavier mesons are non-collective.

The basic principle in this development is chiral symmmetry. The fundamental QCD Lagrangian with originally massless u and d quarks is invariant under the chiral transformation

$$\psi \rightarrow \exp\left[i\gamma_5 \vec{\tau}\cdot\vec{\theta}\right]\psi \tag{6}$$

of the quark fields: the helicity (chirality) $\vec{\sigma}\cdot\hat{p}$ is a conserved quantity for massless free quarks. Lattice calculations[18)] show that chiral symmetry is dynamically broken and the quarks acquire a large (constituent) mass. The pion is the corresponding Goldstone Boson, and its collective features are thought to be intimately related to the chiral symmetry breaking mechanism. G.E. Brown[14)] pointed to the analogy between the pion and the Anderson mode in superconductors, where the dynamical symmetry breaking produces an energy gap in the quasiparticle spectrum, in a similar way as the quarks obtain their constituent mass.

The basic model to demonstrate the chiral symmetry breaking mechanism is that of Nambu and Jona-Lasinio (NJL)[17)]. In fact, almost all modern descriptions of the pion are more or less directly based on the original NJL idea. It starts from massless u and d quarks with a chiral invariant effective Lagrangian

$$\mathcal{L}_{eff} = \bar{\psi} i \gamma_\mu \partial^\mu \psi + G\left[(\bar{\psi}\psi)^2 + (\bar{\psi} i \gamma_5 \vec{\tau} \psi)^2\right]. \qquad (7)$$

When the coupling strength G reaches a certain critical value, the interaction produces a finite quark mass m and the physical vacuum obtains a non-trivial structure by the appearance of a quark condensate, i.e. a non-zero expectation value $\langle\bar{\psi}\psi\rangle$. At the same time, the interaction is strongly attractive in pseudoscalar-isovector quark-antiquark states in such a way that it moves the mass of a pionic $q\bar{q}$ mode down from $2m$ to zero. This is just what is required by the Goldstone theorem.

The NJL mechanism is of a very general nature, independent of the detailed form of the chiral invariant interaction. In fact, one-gluon exchange also leads to chiral symmetry breaking if the effective quark-gluon coupling strength α_s reaches values of order unity[19-23)] (this should not lead to the conclusion, of course, that chiral symmetry breaking is of perturbative origin).

Results of QCD Monte Carlo calculations on the lattice[18)] indicate a close connection between chiral symmetry breaking and confinement. In simple terms, once originally massless quarks are reflected between confining walls, their helicity $\vec{\sigma} \cdot \hat{p}$ is not a good quantum number any more.

c) A schematic model

A schematic model with these properties has been studied in ref. 24 using the language of the random phase approximation (RPA) familiar from nuclear physics. In this model, the coupling constant G of the NJL approach is essentially replaced by a position dependent coupling strength G(r) chosen such that the self consistent procedure for generating the dynamical quark mass m now leads to a scalar potential m(r) which confines quarks. This potential has a series of $q\bar{q}$ bound states carrying pion quantum numbers which we can refer to as the "bag model" pionic states. The lowest one of these states, with the quark and antiquark confined in 1s orbits, should be closest to the physical pion but its mass comes out too large, even with center-of-mass corrections included, unless the radius is chosen unreasonably large.

This is the situation with vanishing residual quark-antiquark interaction. Once the NJL type chiral interaction is turned on in $q\bar{q}$ states with pion quantum numbers, the pion mode emerges as a coherent superposition of the bag model pionic $q\bar{q}$ pairs. Let B^+_α be the creation operator of a single $q\bar{q}$ pair confined in the orbit α of a bag or confining potential m(r). Then the pion is represented as

$$|\pi\rangle = \sum_\alpha \left[X_\alpha B^+_\alpha - Y_\alpha B_\alpha\right] |\tilde{0}\rangle , \tag{6}$$

a form of the wave function familiar from the RPA description of collective modes. The RPA vacuum $|\tilde{0}\rangle$ has a non-trivial structure: it has $(\pi\pi)$ pairs already built into it, in a way analogous to (2 particle-2 hole, ... etc.) ground state correlations in the many-body analogue. The coefficients Y_α measure the degree to which such pairs are present in $|\tilde{0}>$.

For originally massless u and d quarks, the pion mode must end up at zero mass, in accordance with the Goldstone theorem. The actual physical pion with m_π = 140 MeV is obtained with finite but small current quark masses m_u and m_d. The RPA scheme naturally leads to the characteristic relation $m_\pi^2 = \text{const} \cdot (m_u + m_d)$, consistent with the well known current algebra result

$$f_\pi^2 m_\pi^2 = -(m_u + m_d) <\bar{\Psi}\Psi>. \tag{7}$$

The collective properties of the pion can be best illustrated by examining the strength function for pionic excitations $|\pi_n>$ of the physical vacuum:

$$S(E) = \sum_n |<\tilde{0}|\bar{\Psi} i\gamma_5 \vec{\tau}\Psi|\pi_n>|^2 \delta(E-E_n). \tag{8}$$

The pion mode of eq. (6) is then the energetically lowest one of the states $|\pi_n>$. A typical result is shown in Fig. 4. In a pure confining potential or bag model description, the distribution S(E) shows peaks at the masses of the uncorrelated pionic $q\bar{q}$ pairs with roughly equal strengths (see the white columns in Fig. 4). However, after turning on the residual chiral $q\bar{q}$-interaction, the strength is almost completely removed from these states and concentrated in just one collective state with low mass, to be identified with the physical pion (see black columns in Fig. 4). The strength function satisfies an energy weighted sum rule,

$$\int dE\, E\, S(E) = \text{const}. \tag{9}$$

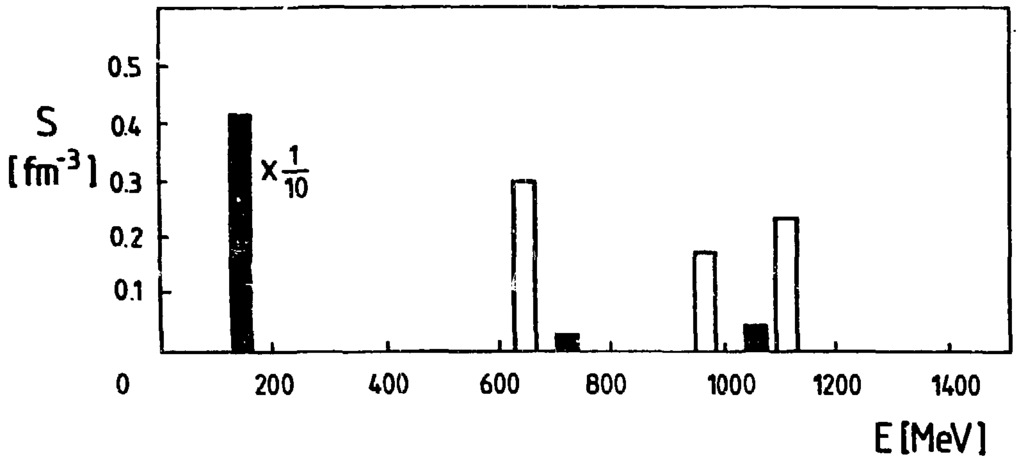

FIGURE 4
Strength distribution of pionic $q\bar{q}$ states below 1.2 GeV. White columns: uncorrelated pionic $q\bar{q}$ states in $(1s)^2$, $(1p3/2)^2$ and $(1p_{1/2})^2$ orbits of typical confining potential. Black columns: the spectrum obtained after turning on the residual chiral interaction between quark and antiquark. The physical pion is obtained at m_π = 140 MeV with $m_{u,d} \simeq$ 20 MeV in this calculation. For details see ref. 24.

One therefore expects to see very little pseudoscalar-isovector strength other than the pion in the empirical meson spectrum. Indeed, the data[25] tables show only weak indications (not well established) of a broad π' resonance around 1300 MeV. On the other hand, the bag model would predict several such π' states as uncorrelated $q\bar{q}$ pairs in orbits higher than 1s. The chiral invariance of the NJL effective interaction implies that only the pion mode becomes collective, whereas vector meson states such as the ρ and the ω are left almost unperturbed at their "bag model" positions.

As expected for low-lying collective states, one finds that the pion wave function has admixtures of multi-$q\bar{q}$ components, closely analogous to ground state correlations in descriptions of low energy collective particle-hole states. Thus the single $q\bar{q}$ component in a Fock space representation of the pion is strongly reduced. In a decomposition of $|\pi\rangle$ analogous to eq. (4) one finds typical values of the single $q\bar{q}$-probability around $Z \simeq 0.3$.

The pion decay constant is obtained in the form

$$f_\pi = \sqrt{3}\, m_\pi^{-1/2} \sum_\alpha (X_\alpha - Y_\alpha)\, \phi_\alpha(0), \tag{10}$$

where $\phi_\alpha(0)$ is essentially the amplitude to find a $q\bar{q}$-pair in an orbit α of a bag (or confining potential) at the origin, $r = 0$. The collective features of the pion show up in the characteristic X-Y dependence. It is important to note that the combination $(X-Y)m_\pi^{-1/2}$, and therefore f_π itself, turns out to be independent of m_π. This is consistent with basic current algebra requirements.

In a combined analysis with the $\pi^0 \to 2\gamma$ decay, the decay constant f_π comes out as in eq. (5) with pion r.m.s. radii of about 0.4 fm. The conclusions appear to be similar as those reached by Brodsky et al., although a direct comparison is not possible since the phenomenology of ref. 16 works with current quarks in the infinite momentum frame, whereas the collective pion is described in terms of quarks dressed by the confining potential.

The fact that the pion decay constant f_π sets a constraint for the ratio $\sqrt{Z}/R_\pi$ is of some significance. In the RPA description of the pion, the wave function contains n quark - n antiquark components where n = 1,3,5, ... etc., but no $2q2\bar{q}$ admixtures. On the other hand, the empirical pion form factor in the region of timelike q^2 (see Fig. 2) and the large $\rho \to \pi\pi$ decay width suggest a strong $\pi \leftrightarrow \rho\pi$ coupling and therefore a non-negligible $\rho\pi$ admixture in the pion wave function. These and other additional components would tend to reduce the single $q\bar{q}$ probability Z even further. In order to leave f_π unchanged, the radius R_π must be reduced accordingly. One therefore expects that $R_\pi \sim 0.4$ fm is probably an upper limit.

CONCLUDING REMARKS

There exist two opposing views of the pion: that of a single strongly bound $q\bar{q}$ pair[26], and the description in terms of a collective excitation of the non-perturbative QCD vacuum. The pion as a single bound $q\bar{q}$-pair would have an r.m.s. radius comparable to the measured charge radius. Its connection with the Goldstone Boson aspect is difficult to understand; the small pion mass does not arise naturally in such a picture. The main virtue of the collective model is that it provides a link between the Goldstone Boson nature and the $q\bar{q}$ substructure of the pion[27]. The collective pion has a strongly reduced single $q\bar{q}$ component and a small radius ($R_\pi < 0.4$ fm).

A collective pion of small size would justify, to some extent, the introduction of a pointlike pion field in chiral bag or soliton models. It would also help to understand why the one-pion exchange nucleon-nucleon interaction works so accurately in the long wavelength limit, down to distances comparable to the pion Compton wave length.

REFERENCES

1) H. Yukawa, Proc. Phys.-Math. Soc. Japan 17 (1935) 48

2) T.E.O. Ericson and M. Rosa-Clot, Nucl. Phys. A 405 (1983) 497

3) see the compilation of O. Dumbrajs et al., Nucl. Phys. B 216 (1983) 277, and refs. therein

4) G.E. Brown and M. Rho, Phys. Lett. 82 B (1979) 177;
V. Vento et al., Nucl. Phys. A 345 (1980) 413

5) G.A. Miller, A.W. Thomas and S. Théberge, Phys. Lett. 91 B (1980) 192;
Phys. Rev. D 22 (1980) 2823

6) A.W. Thomas, Adv. in Nucl. Phys. 13 (1984) 1;
G.A. Miller, Int. Rev. of Nucl. Phys. 1 (1984), in print

7) E. Oset, R. Tegen and W. Weise, Nucl. Phys. A 426 (1984) 456;
W. Weise, Int. Rev. of Nucl. Phys. 1 (1984), in print

8) T.H.R. Skyrme, Nucl. Phys. 31 (1962) 556

9) E. Witten, Nucl. Phys. B 222 (1983) 433

10) M. Rho, A.S. Goldberger and G.E. Brown, Phys. Rev. Lett. 51 (1983) 747;
A.D. Jackson and M. Rho, Phys. Rev. Lett. 51 (1983) 751

11) S.L. Adler, Phys. Rev. 177 (1969) 2426;
J.S. Bell and R. Jackiw, Nuovo Cim. 51 (1969) 47

12) S.R. Amendiola et al. (NA 7 collaboration), CERN preprint EP 84-59 (1984);
E.B. Dally et al., Phys. Rev. Lett. 48 (1982) 375

13) S.R. Amendiola et al., Phys. Lett. 138 B (1984) 454, and refs. therein

14) G.E. Brown, Nucl. Phys. A 358 (1981) 39c; Progr. Part. Nucl. Phys. 8 (1984)14[illegible]

15) J. Badier et al. (NA 3 collaboration), Z. Physik C 18 (1983) 281

16) S.J. Brodsky and G.P. Lepage, Phys. Scripta 23 (1981) 945;
S.J. Brodsky, Springer Tracts in Mod. Phys. 100 (1982) 81

17) Y. Nambu and G. Jona-Lasinio, Phys. Rev. 122 (1961) 345, 124 (1961) 246

18) J. Kogut, M. Stone, H.W. Wyld, J. Shigemitsu, S.H. Shenker and D.K. Sinclair, Phys. Rev. Lett. 48 (1982) 1140

19) T. Goldman and R.W. Haymaker, Phys. Rev. D 24 (1981) 724, 743

20) J. Finger and J. Mandula, Nucl. Phys. B 199 (1982) 168;
J. Govaerts, J. Mandula and J. Weyers, Phys. Lett. 130 B (1983) 427

21) A. Amer, A. le Yaouanc, L. Oliver, O. Pène and J.C. Raynal, Nucl. Phys. B 214 (1983) 299, Phys. Rev. D 28 (1983) 1530, Z. Physik C 17 (1983) 61

22) V.A. Miransky, V.P. Gusynin and Y.A. Sitenko, Phys. Lett. 100 B (1981) 157

23) M.D. Scadron, Rep. Progr. Phys. 44 (1981) 213

24) V. Bernard, R. Brockmann, M. Schaden, W. Weise and E. Werner, Nucl. Phys. A 412 (1984) 349; R. Brockmann, W. Weise and E. Werner, Phys. Lett. 122 B (1983) 201

25) Particle Data Group, Rev. Mod. Phys. 56 (1984) No. 2

26) N.H. Fuchs and M.D. Scadron, Arizona State Univ. preprint (1984)

27) S. Stokar, Phys. Rev. Lett. 51 (1983) 23

DELTA DYNAMICS IN NUCLEI

by

E. Piasetzky

I. INTRODUCTION

Pion-nucleon scattering at intermediate energies is dominated by the existence of the strong Δ(1232) resonance in the p-wave channel (see Fig. 1). The Δ resonance has a spin and isospin of 3/2, a mass of 1232 MeV, and a width of 115 MeV. The strong coupling of $\pi N \rightarrow \Delta$ means that the pion-nucleus interaction at these energies can be described in terms of Δ creation, propagation, interaction, and decay in the nuclear medium. A typical distance for free Δ propagation is $d_\Delta = (p_\pi/m_\Delta)(\Gamma/2) \sim 1$ fm, which is small compared to nuclear radii and comparable to average internucleon spacing $d_N \sim 2$ fm. In a nuclear medium the Δ can be affected by decay modes like $N\Delta \rightarrow NN$, which are not open in the free space. The approximate equality of inelastic scattering and absorption cross sections implies that the mean-free path for Δ absorption in a process like this is $d_{abs} \sim 1$ fm.

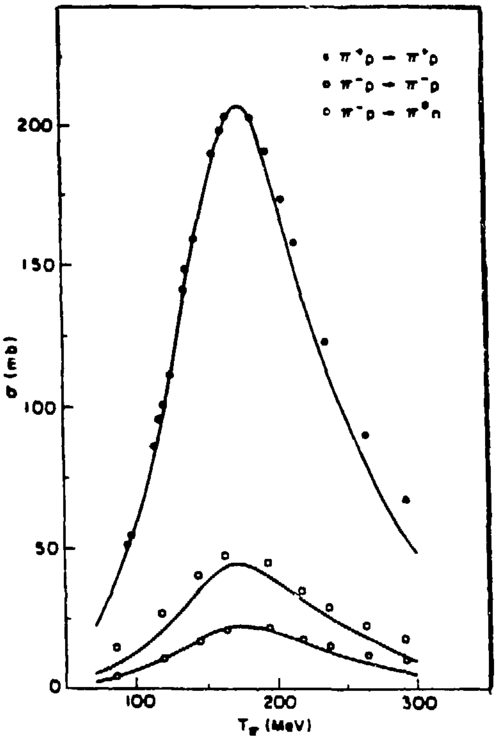

Fig. 1. Δ dominance of the pion-nucleon interaction. The lines are the contributions from the resonant p-wave partial wave only.

Moreover, the typical momentum of the pion/Δ resonance is of the same order of magnitude as the Fermi momentum of nucleons in the nucleus. From these length and energy scales it is clear that one can expect a large modification of the Δ properties by the nuclear medium. It is the task of this talk to discuss the Δ-nucleus dynamics that can be deduced from study of pion-nuclear reactions.

Before discussing the essential subject, I would like to emphasize the general interest in studying Δ dynamics. As was mentioned, an understanding of the Δ-nucleus interaction is essential for the understanding of π-nucleus interaction at intermediate energies, but that is not the only area in which Δ dynamics plays an important role. The importance of the Δ dynamics in understanding photonuclear reactions, as well as inclusive electron scattering, is demonstrated in Figs. 2 and 3. The calculations presented in these figures emphasize the strong sensitivity to the Δ degree of freedom.

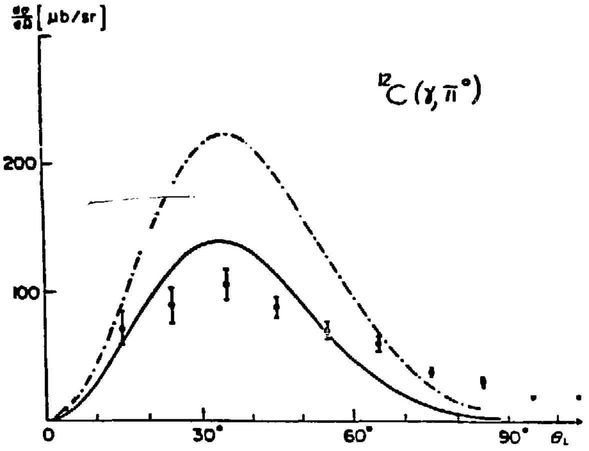

Fig. 2. Angular distribution for coherent $^{12}C(\gamma,\pi^0)$ with E_γ = 235 MeV. The data are from Ref. 1 and the calculation from Ref. 2. The solid line is the full calculation. The dot-dashed curve presents the results of the same calculation but without Δ spreading potential.

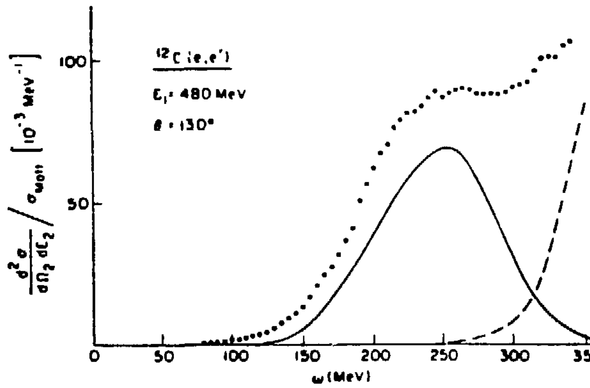

Fig. 3. Spectrum of electrons from the reaction $^{12}C(e,e')$. The incident electron energy is 480 MeV, the outgoing angle is 130°, and ω is the energy loss by the electron. The solid curve is the predicted contribution from quasi-free scattering on the nucleons in the target and the dashed curve from quasifree Δ excitations (more details in Ref. 3).

A $\bar{p}N$ annihilation at rest creates an average of five pions that are at the relevant energy to produce Δ resonances. These Δ resonances, as we discuss later, might then breed further Δ resonances and a local cold "Δ matter" can be created, as recently suggested.[4] In relativistic heavy-ion collisions a large multiplicity of pions, therefore Δ's, is expected.

The existence of a pronounced and isolated resonance in the pion-nucleon system, as is the Δ(1232), allows us to study the Δ dynamics as an example of how a resonance interacts with other hadrons and how its properties are being modified in a many-body, strong-interacting system. Moreover, understanding all the nuclear processes mentioned above requires study of the Δ-nucleus dynamics. The basic interaction is that of the Δ with a nucleon. In the rest of the talk we focus on experimental study of this interaction, emphasizing the isospin dependence of it.

II. ΔN INTERACTION IN ISOSPIN T = 1

A. Pion (Delta) True Absorption (Two-Nucleon Process)

The NΔ interaction can proceed via T = 1 or T = 2 isospin channels. The true absorption on two nucleons is a filter for the T = 1 channel, since the two nucleons in the final state cannot be in the isospin T = 2 state. The pion absorption on a deuteron (spin-triplet, isospin-singlet S-state two-nucleon state) was extensively studied experimentally and theoretically over the last few decades.[5] This process is dominated by an intermediate ΔN state, which has isospin T = 1, relative angular momentum $L'_{\Delta N} = 0$, and $J^{\pi}_{N\Delta} = 2^{+}$. The process is presented schematically in Fig. 4. Only in the last few years was an experimental study of pion absorption on

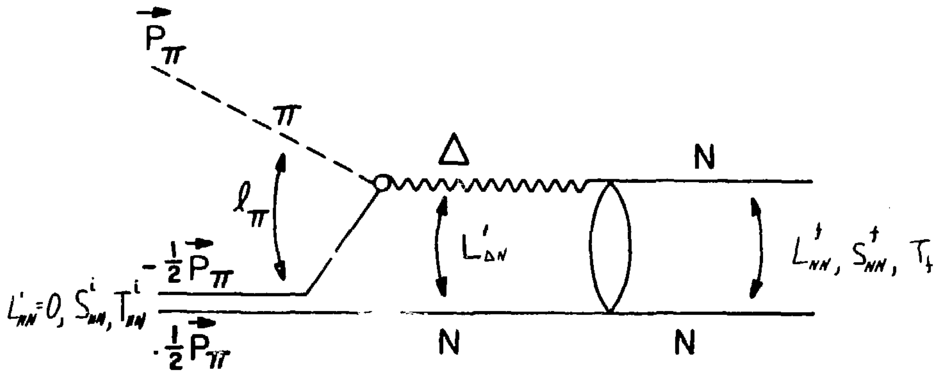

Fig. 4. Schematic presentation of pion absorption on two nucleons via NΔ intermediate state.

a two-nucleon pair in spin singlet, isospin triplet performed. There is no bound state of two nucleons in the S = 0, T = 1 state, and therefore the most straightforward experimental way to study absorption a on a T = 1 pair is to study the (π^-,pn) reaction on ^3He in the selective kinematic conditions that minimize the energy transferred to the undetected nucleon. In the ground state of ^3He the two-proton pair has the required spin and isospin and is, to a good approximation, in a relative S state. If there were no dynamical constraints, and assuming the absorption process is $\pi NN \rightarrow \Delta N \rightarrow NN$, the cross section for absorption on a T = 1 pair is expected to be one-half of the cross section for absorption on a T = 0 pair ($\sigma_1/\sigma_0 = 1/2$). Taking into account the number of pairs in ^3He and the isospin of the initial state, one can calculate the expected ratio $R(^3He)$ defined in Eq. (1)

$$R(^3He) \equiv \frac{\sigma(\pi^+,2p)}{\sigma(\pi^-,pn)} = \frac{\sum_{T_i=0,1} \langle 1\ 1 T_i 0 | 1\ 1\rangle^2 N^{np}_{T_i} \sigma_{T_i}}{\langle 1\ -1\ 1\ 1 | 1\ 0\rangle^2 N^{pp}_{T=1} \cdot \sigma_1} \quad . \tag{1}$$

For ^3He $N^{pp}_{T=1}$, $N^{np}_{T=0}$, $N^{np}_{T=1}$ are 1, 1.5, and 0.5, respectively. Thus for $\sigma_1/\sigma_0 = 1/2$ $R(^3He) = 6.5$.

Recent measurements of this ratio done at LAMPF,[6] TRIUMF,[7] and SIN[8] are presented in Fig. 5, together with the naive expectation calculated in Eq. (1). The main conclusions from all these experiments are as follows.

(1) The cross section for the two-body $(\pi^+,2p)$ reaction in ^3He is roughly equal to the number of np pairs in ^3He times the cross section for $\pi^+d \rightarrow 2p$.

(2) The cross section for the (π^-,pn) reaction on ^3He is strongly suppressed (see Fig. 5). This suppression is energy dependent.

(3) Partial-wave analysis of the correlation between the outgoing nucleons is exploring the nature of the process. There is a strong correlation between the allowed partial waves and the type of particles, spin, and isospin of the intermediate state.

The reason for the measured suppression is believed to be dynamical, involving the orbital angular momenta allowed in the $N\Delta$ intermediate states that generally dominate the absorption mechanism. Pion absorption in a T = 1 $^1S_0$ nucleon pair cannot produce an $N\Delta$ intermediate state in $L'_{N\Delta} = 0$,

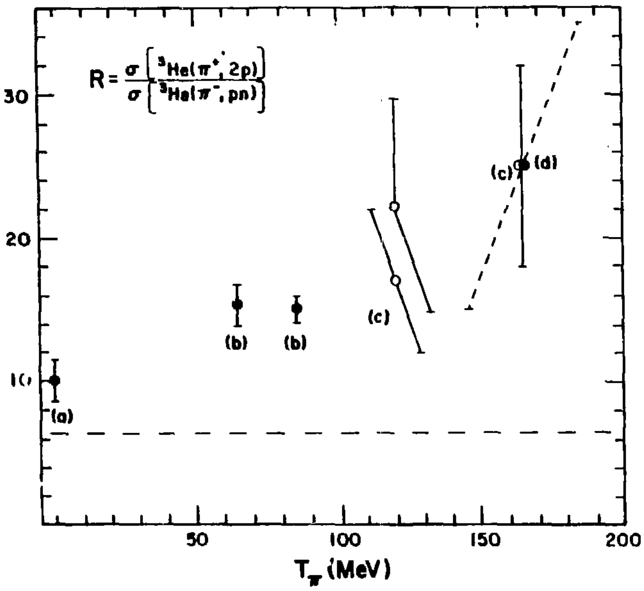

Fig. 5. Ratio of cross section for two-body (π^-,pn) and (π^+,2p) [or (π^-,2n) for stopped pions] on ^{3}He. The broken line corresponds to the expected ratio without dynamical suppression as calculated in Eq. (1). Full points correspond to a large angular-range measurement, whereas empty points correspond to measurements at one conjugate angles set. The results are from (a) Ref. 9, (b) Ref. 7, (c) Ref. 8, and (d) preliminary results of Ref. 6.

a state that dominates the process for the T = 0 pair. The reduction of the NΔ $L'_{N\Delta} = 0$ contribution in absorption on T = 1 provides us with a unique process sensitive to small effects in the πNN or NΔ system that are otherwise masked by the dominant intermediate state. Such processes might be an NΔ intermediate state with higher angular momentum,[10,11] an NN′ (N′ is T = 1/2 πN state) intermediate state,[12] six-quark clusters,[13] or any other mechanism in which the Δ does not play a major role.

Turning to heavier nuclei, the quasi-free two-body absorption process can be identified and measured in coincidence experiments using the preferred kinematics for the two-body process, as demonstrated in Figs. 6-8.

What are the facts that can be deduced from the last few years' coincidence measurements concerning the two-body absorption on heavy nuclei?

(1) The quasi-free two-body absorption contribution to the total absorption cross section is small.[14] For example, on ^{12}C it does not exceed 25% (after taking into account final-state interaction). This result is consistent with previous single-arm measurements,[15] which indicate that the average number of nucleons

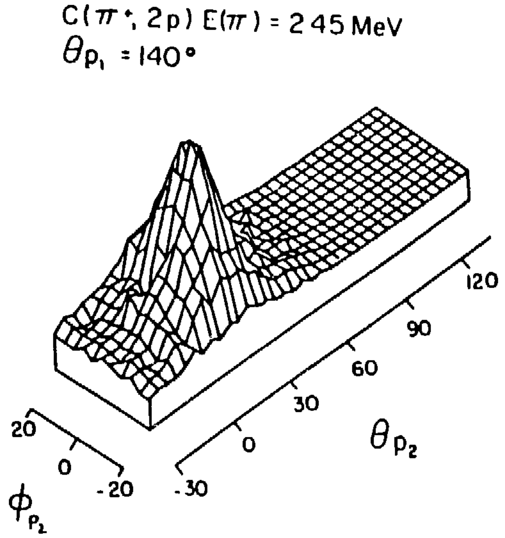

Fig. 6. Proton-proton angular correlation in the $^{12}C(\pi^+,2p)$ reaction. T_π^{in} = 245 MeV, θ angle in the reaction plane, and φ perpendicular to it.

participating in the absorption process is larger than two (equal to 4 ± 1).

(2) <u>The quasi-free two-body absorption on a T = 1 nucleon pair at the resonance energy seems to be suppressed as in few-body systems.</u>

In nuclei heavier than ^{4}He, T = 1 nucleon pairs are not necessary in relative S wave and therefore an intermediate NΔ in $L'_{N\Delta} = 0$ is not prevented by the Pauli principle. Moreover, it is not clear á priori that the quasi-free two-body absorption in heavy nuclei will be dominted by the NΔ $L'_{N\Delta} = 0$ intermediate state. However, experimental results that will be discussed later seem to indicate that there is a suppression of the absorption on a T = 1 pair. This measured fact is consistent with the dominance of T = 1 $L'_{N\Delta} = 0$ NΔ intermediate state in the quasi-free two-body absorption on heavy nuclei as it is in few-body systems. The S wave between the two initial nucleons in this case, although not determined by the ground-state properties of the nucleus, is probably enforced by the kinematics (high-momentum transfer). What are the experimental results that indicate these facts?

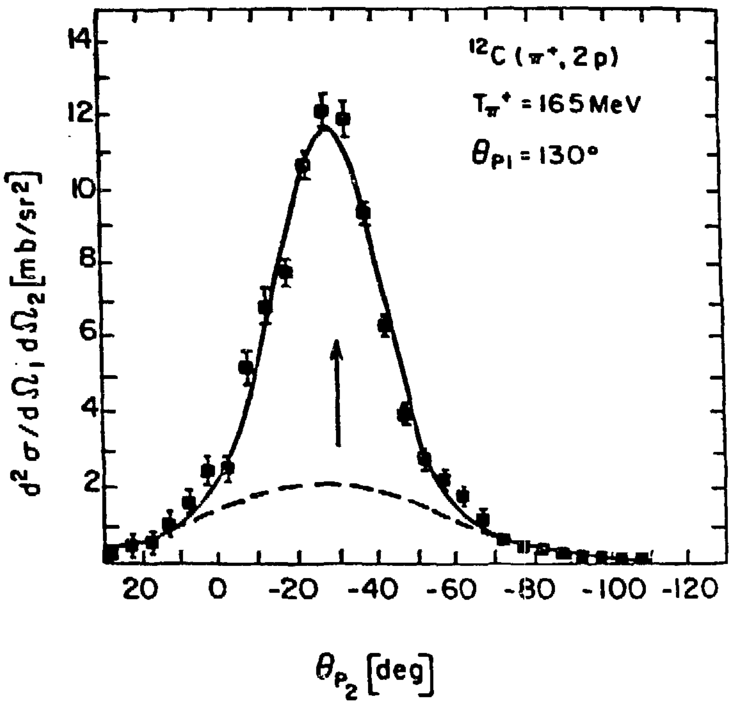

Fig. 7. A slice $\phi = 0^{\circ} \pm 6^{\circ}$ of a proton-proton angular correlation for T_{π}^{in} = 165 MeV $\theta p_1 = 130^{\circ}$.

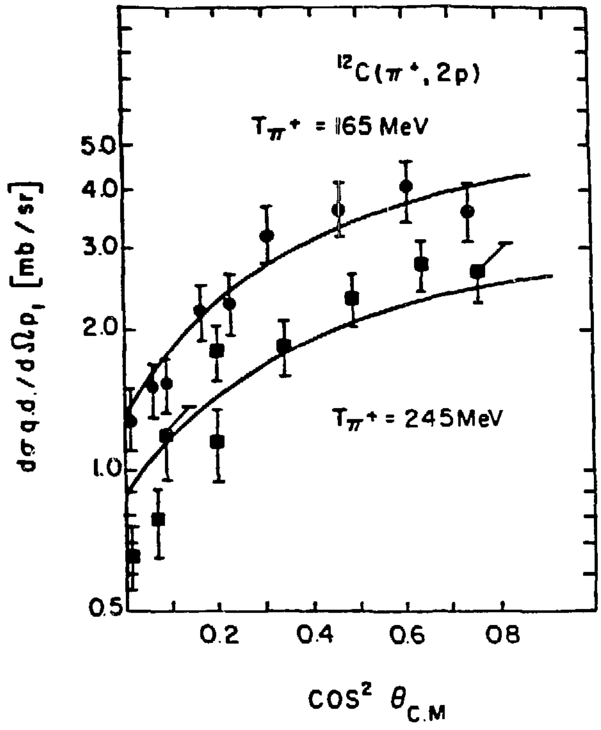

Fig. 8. Angular distributions of the two-body quasi-deuteron $(\pi^+,2p)$ reaction at 165 and 245 MeV. The curves are the $\pi^+ d \rightarrow 2p$ angular distributions normalized to the data.

(1) S wave between the two initial nucleons: Table I presents results of different pion-induced reactions measured on ^{16}O and ^{18}O. This table is divided into three groups. The first four reactions involve mostly neutrons; the second group contains reactions involving mainly protons; and the last group includes the cross section for π^+ absorption and $(\pi^+,2p)$. The absorption cross section on ^{18}O is greater by 20%, an amount consistent with the suppression in the cross sections corresponding to the second group. However, the $(\pi^+,2p)$ difference between the isotopes, which must be related to absorption on an (n-p) pair in different shells $(L'_{NN} = 0)$, is only 5%.

(2) S wave between the two initial nucleons: more experiments[20,21] involving high-resolution studies of the $^{18}O(\pi^+,2p)$ reaction are expected in the near future at SIN and TRIUMF to address this question.

(3) Suppression of absorption on T = 1 pairs: preliminary results[19] of the $(\pi^-,pn)/(\pi^+,2p)$ ratio on heavy nuclei show that it is only a few per cent (^{12}C--2.5 ± 0.8%; Bi--3.5 ± 1% at 165 MeV).

TABLE I. Cross-section ratios for several pion-induced reactions on ^{18}O and ^{16}O at bombarding energy of 165 MeV.

Reaction	$\sigma(^{18}O)/\sigma(^{16}O)$	Reference
(π^-,π^-n)	1.25 ± 0.09	16
$(\pi^-,\pi^{-\prime})$	1.22 ± 0.11	17
(π^+,π^0)	1.39 ± 0.03	18
(π^+,pn)	1.14 ± 0.10	19
(π^+,π^+p)	0.83 ± 0.03	16
(π^-,π^-p)	0.83 ± 0.07	16
$(\pi^+,\pi^{+\prime})$	0.84 ± 0.08	17
(π^-,π^0)	0.88 ± 0.05	18
(π^-,pn)	0.83 ± 0.07	19
π^+ abs[a]	1.17 ± 0.05	17
$(\pi^+,2p)$	1.05 ± 0.03	19

[a]Value obtained from reanalysis of data from Ref. 17 and recently measured SCX cross sections (Ref. 18).

(4) Suppression of absorption on T = 1 pairs: gamma-ray spectra in prompt coincidence with pion absorption indicate that levels of the residual nuclei that correspond to absorption on np pairs in the T = 1 state are strongly suppressed.[22]

To close the discussion on the quasi-free two-body absorption on heavy nuclei, I relate the measured results to the microscopic description in terms of Δ dynamics. As in few-body systems, the quasi-free two-body process seems to be dominated by the NΔ T = 1 $L'_{N\Delta} = 0$ intermediate state. This quasi-free two-body process, which is the simplest absorption process, is only a small fraction of the total absorption cross section. The question of the mechanism responsible for the rest of the total absorption is still open. Other processes that might be responsible for the bulk of the absorption cross section are multiple pion scattering followed by a final two-nucleon absorption,[23-25] absorption on clusters, or double-Δ formation.[26] We resume the discussion on this subject when we discuss the NΔ interaction with T = 2.

B. Inclusive $(\pi^+,\pi^{+\prime})$ and $(\pi^+,\pi^{0\prime})$ Reactions

In the previous section we showed that the absorption on a T = 1 relative S-state nucleon pair is very weak. Can we see indications to this effect in pion-induced reactions other than two-body absorption? The answer is yes. Figure 9 presents energy spectra from the $^{16}O(\pi^+,\pi^{+\prime})$ and $^{16}O(\pi^+,\pi^{0\prime})$ inclusive measurement at SIN[27] and LAMPF.[18] The ratio of the scales is that of the corresponding πN reactions. Also shown are calculations[28] based on the Δ-h model. The solid line is a full calculation explicitly including a coupling to the absorption channel via the NΔ → NN interaction. The dashed curves correspond to the same calculation without taking into account the medium modification due to the NΔ interaction. As can be seen in the figure, both the two calculations and the two reactions look similar at high energies (quasi-free region), but at low energies (multistep process) there is a larger tail to the $(\pi^+,\pi^{0\prime})$ reaction, which seems to be in good agreement with the calculations, excluding the coupling to the absorption channel. That effect might be related to the ΔT = 1 nature of the charge-exchange reaction and the suppression of the absorption on T = 1 nucleon pairs. For the isovector excitation involved in the $(\pi^+,\pi^{0\prime})$ reaction, a coupling to the absorption channel via the NΔ → NN interaction involves, with some assumptions, a coupling of NΔ, T = 1 to a

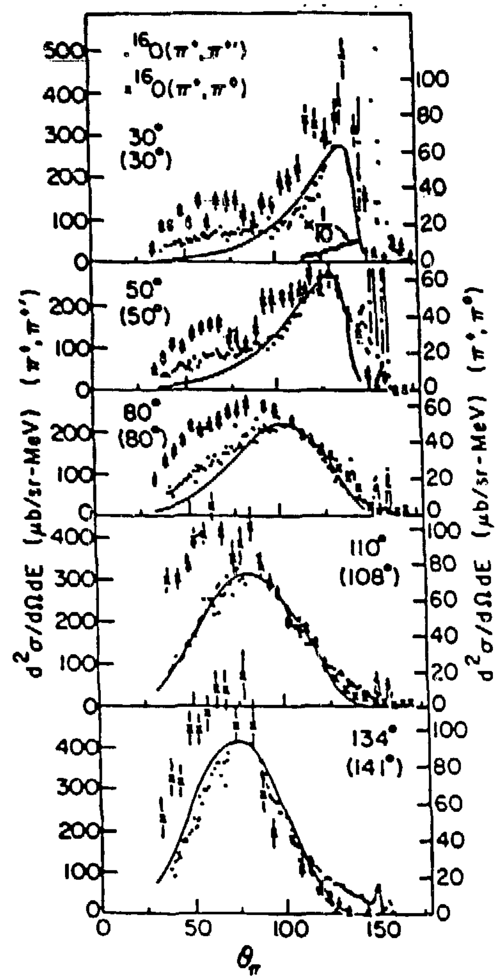

Fig. 9. Outgoing pion spectra from the reactions $^{16}O(\pi^+,\pi^{+\prime})$ at 163 MeV (Ref. 27) and $^{16}O(\pi^+,\pi^{0\prime})$ at 160 MeV (Ref. 18). The ratio of the scales is that of the corresponding pion-nucleon reactions. Angles in parentheses are for the $(\pi^+,\pi^{0\prime})$ reaction. The lines are theoretical calculations (Ref. 28) using the Δ-h model (solid lines) and the closure approximation (dashed line).

$T = 1$, $L_{NN} = 0$ nucleon pair which, as we discussed earlier, is strongly suppressed. Therefore the multipstep processes (shown as a low-energy tail in the spectrum) are not as strongly truncated in the $(\pi^+,\pi^{0\prime})$ reaction as they are in the $(\pi^+,\pi^{+\prime})$ case.

C. Quasi-Free Nucleon-Knockout Reactions

Unlike the situation in total absorption where we found that one-step Δ formation followed by NΔ → NN interaction is only a small part of the absorption, a one-step Δ formation and decay is the dominant contribution to the inelastic scattering. There are few experimental results coming from coincidence and single-arm measurement of the quasi-free knockout reactions that can illuminate different aspects of Δ dynamics in general and the Δ-N interaction in particular. Due to the limited scope of this talk we will concentrate on only one of these: the ratio (π^+,π^+p) to (π^-,π^-p) and (π^+,π^+p) to (π^+,π^0p) quasi-free (qf) scattering.

As in the case of the two-body absorption process, a coincidence measurement of the outgoing particles allows identification of the quasi-free process. In early coincidence measurements[16] of the ratio $\sigma_{qf}(\pi^+,\pi^+p)/\sigma_{qf}(\pi^-,\pi^-p)$, the direct knockout strength was deduced from the π-p angular correlation only (see Figs. 10 and 11). In a recent coincidence experiment[29] both angles and energies of the outgoing particles were measured. The missing mass resolution was about 3 MeV and was sufficient to identify the ground state of the daughter nucleus, which is dominantly populated by direct $p_{1/2}$-shell proton knockout (see Fig. 12). Both of these measurements report consistent strong deviations of the ratio $\sigma_{qf}(\pi^+,\pi^+p)/\sigma_{qf}(\pi^-,\pi^-p)$ from the free ratio $\sigma(\pi^+p \to \pi^+p)/\sigma(\pi^-p \to \pi^-p)$, as can be seen in Figs. 13 and 14. The quasi-free ratio is about three times bigger than the free ratio at the most forward π angle measured. This large ratio implies that the quasi-free knockout process itself is substantially modified, since this ratio cannot be explained by simple impulse approximation. The strong (π^+,π^+p) is unlikely to be enhanced by so large a factor; therefore the primary effect must be related to suppression of the (π^-,π^-p)

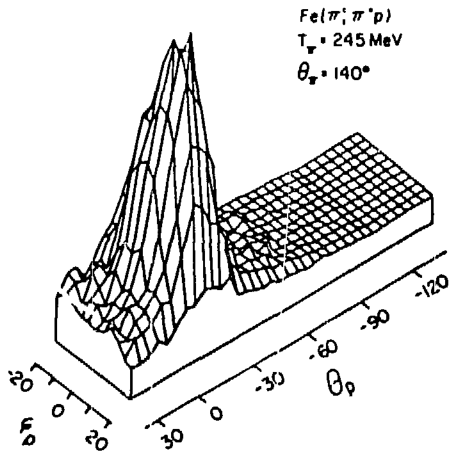

Fig. 10. Pion-proton angular correlation in the $^{12}C(\pi^+,\pi^+p)$ reaction. The incident pion energy is 245 MeV, the pion angle is 140°, θp is the proton angle in the reaction plane, and ψ_p perpendicular to it.

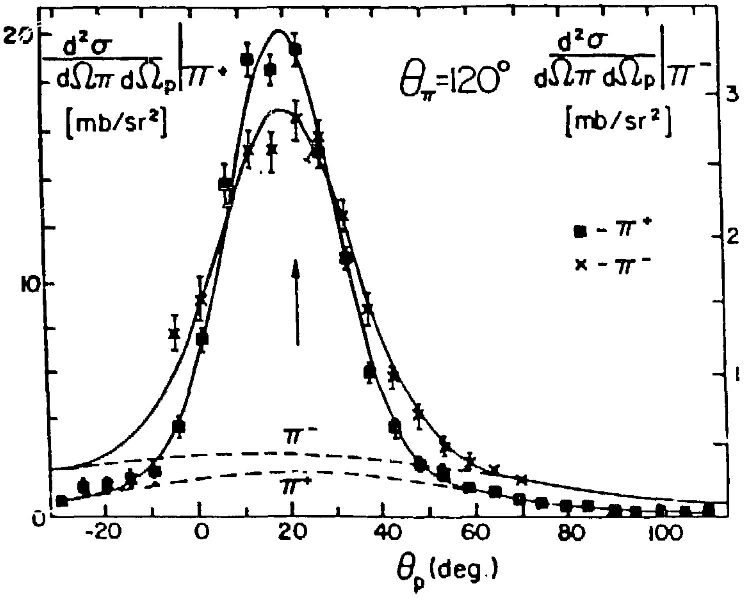

Fig. 11. Slices of the π-p angular correlation along the reaction plane with width of $\Delta\psi_p = 0 \pm 6^\circ$ for $^{12}C(\pi^+,\pi^+p)$ (π^+, squares, and π^-, crosses). Each solid curve is the result of a two-Gaussian fit to the data. The arrow marks the angle for the free π-p scattering. The dashed curves are the broad Gaussians. The incident pion energy is 245 MeV. The scale for π^- scattering (right) is that for π^+ scattering (left) multiplied by the ratio of free π^-p/π^+p scattering cross sections.

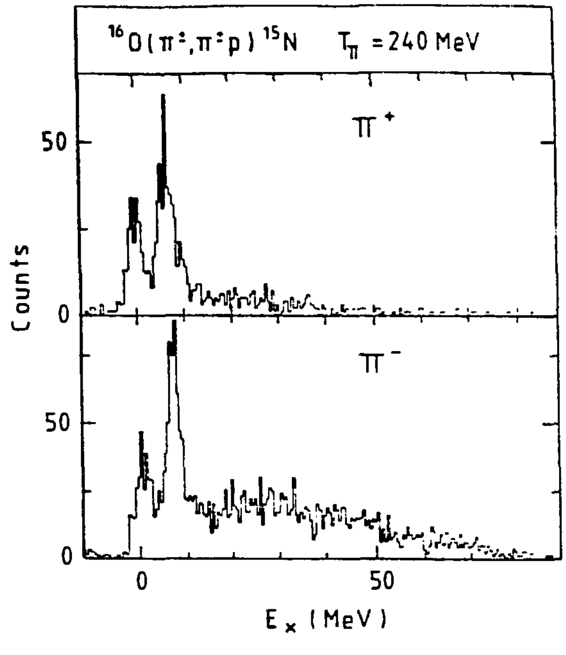

Fig. 12. Excitation-energy spectra of the residual ^{15}N nucleus for $^{16}O(\pi^+,\pi^+p)^{15}N$ and $^{16}O(\pi^-,\pi^-p)^{15}N$ reactions. The incident energy is 240 MeV, the pion angle is 60°, and the proton angle is -35°.

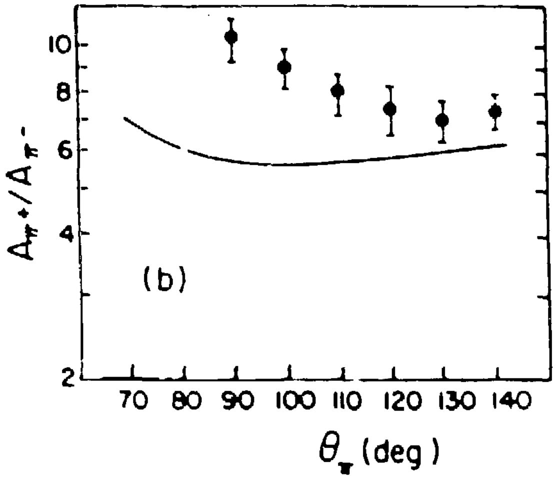

Fig. 13. Ratio of the quasi-free π^+ to π^- cross sections. The curve is the free π^+p to π^-p cross-section ratio.

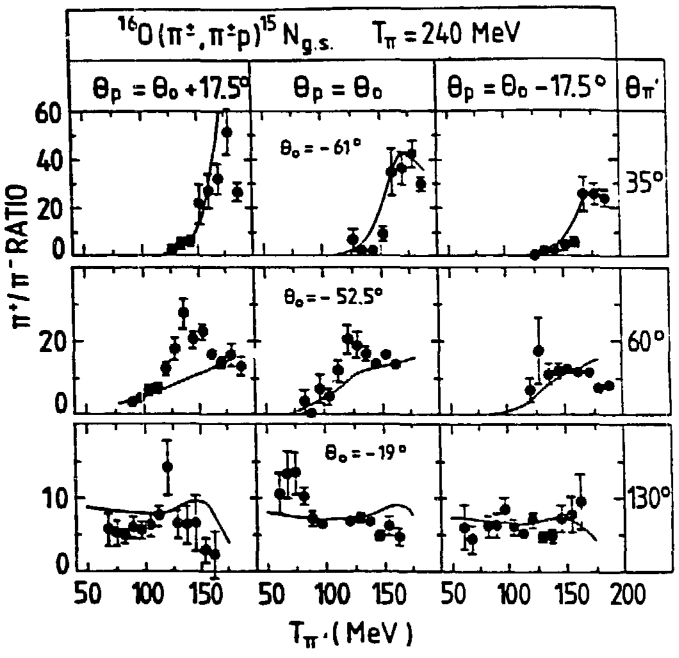

Fig. 14. Ratio of π^+- to π^--induced cross sections to the $^{15}N_{g.s.}$ in each proton telescope compared to the estimates (solid curves), including Δ-N knockout. (See text and Ref. 29 for details.)

cross section. Hirata, Lenz, and Thies[30] suggested that a ΔN interaction can cause this effect. The mechanism they suggested is that the Δ interacts with another nucleon in the nucleus. As a result of this interaction the other nucleon is knocked out, whereas the nucleon emerging from the Δ

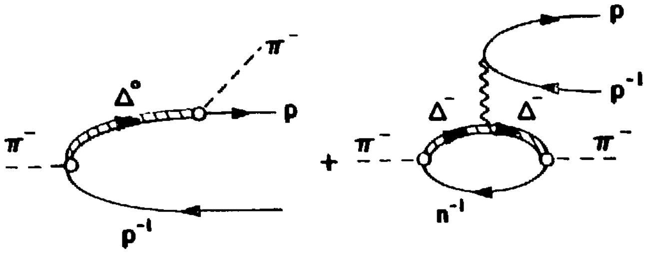

Fig. 15. Illustration of the direct quasi-free (a) and ΔN interaction (b) contributions to the (π^-,π^-p) reaction.

decay is recaptured in the nucleus (see Fig. 15). As in the case of the two-body absorption, this ratio of quasi-free knockout reactions is a filter for ΔN in the T = 1 interaction. The T = 2 NΔ intermediate state must lead to the T = 3/2 πN state and therefore would not cause a change in the ratio compared to the free one. Simple calculations[29] assuming that the modification to the ratio is due to interference between the direct π^-p amplitude and Δ-N knockout amplitude (ΔN is in T = 1, S = 2, $L_{\Delta N} = 0$ channel) are presented with the data in Fig. 13. These calculations are in good agreement with the data.

This model for explaining the $\sigma_{qf}(\pi^+,\pi^+p)/\sigma_{qf}(\pi^-,\pi^-p)$ ratio has a clear prediction for the ratio of $\sigma_{qf}(\pi^+,\pi^+p)/\sigma_{qf}(\pi^+,\pi^0p)$. If this interference between direct and ΔN knockout amplitudes is the dynamical reason, then one expects that the $\sigma(\pi^+,\pi^+p)$ to $\sigma(\pi^+,\pi^0p)$ ratio will be modified the other way (constructive interference), but the overall effect will be smaller.[31]

A collaboration consisting of people who made the two measurements of the $\sigma_{qf}(\pi^+,\pi^+p)/\sigma_{qf}(\pi^-,\pi^-p)$ ratio and people from MIT and LAMPF set a new experiment[32] to measure $\sigma_{qf}(\pi^+,\pi^0p)$ on ^{16}O in order to construct the $\sigma_{qf}(\pi^+,\pi^+p)/\sigma_{qf}(\pi^+,\pi^0p)$ ratio. The experiment consisted of measurements in coincidence of the π^0 (with the π^0 spectrometer) and the proton (with a special p-arm built for this experiment). The experiment finished taking data a week before this meeting. The reaction $^{16}O(\pi^+,\pi^0p)$ was measured at T_π = 245 and 165 MeV for the π^0 angles between 30 and 130°. At each angle the protons were detected by using an array of plastic scintillator telescopes, which covered the quasi-free angular-correlation region. The data are in process of analysis. Preliminary results from the first running time indicate that the quasi-free process (a knockout of a p-shell nucleon) can be identified (see Fig. 16). When analysis is complete, we hope that it will either confirm the model suggested or shed new light on the process.

III. NΔ INTERACTION AT T = 2

A. The NΔ → ΔΔ Transition and Pion Absorption

As we mentioned earlier, the data indicate that the pion absorption on nuclei is not dominated by a single-step Δ production followed by NΔ → NN transition, a process we call in this talk a quasi-free two-body absorption. This process is the dominant process in pion absorption on the deuteron and is the simplest process that can be expected in nuclei. To focus the discussion, I mention now the experimental indication in a coherent way. Part of them we discussed earlier in other contexts.

(1) Rapidity analysis of nucleon spectra seen after pion absorption[15] indicate that the number of nucleons participating in the absorption process is about 4 ± 1 for both π^+ and π^-.

(2) The ratio of protons from π^+ vs π^- absorption for a pion bombarding energy of 220 MeV is $R = Y_p(\pi^+)/Y_p(\pi^-) = 4 \pm 0.6$, independent of the proton angle.[15] Direct two-nucleon absorption without final-state interactions of the outgoing protons would result in a value of R larger than 10, since the dominant two-body reaction for π^- is $(\pi^-,2n)$.

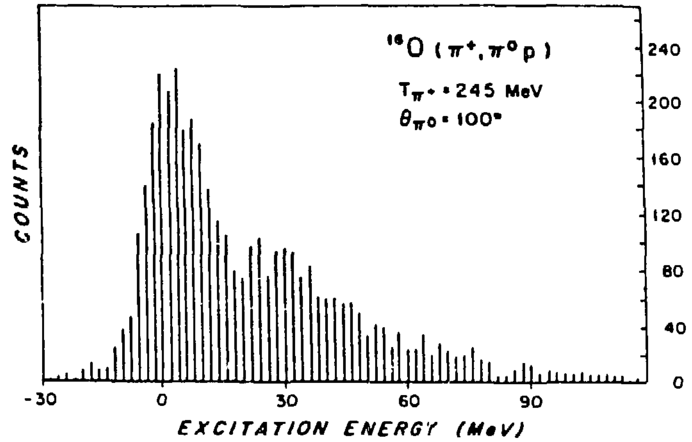

Fig. 16. Excitation-energy spectra of the reaction $^{16}O(\pi^+,\pi^0p)$. The incident energy is 245 MeV and the π^0 and p are at conjugate angles.

(3) The energy distribution for protons resulting from π^+ and π^- absorption[15] are almost equal, contradicting the fact that for direct two-nucleon absorption the (π^-,p) protons are mainly "secondary protons."

(4) As was discussed in detail earlier, coincidence measurements[19] of the two outgoing nucleons show that a direct two-nucleon absorption is only a small fraction of the total absorption cross section.

(5) Photon- and pion-induced proton-emission spectra at comparable energies have similar shape and differ only by an overall factor. This is an experimental indication of the fact that the proton mean-free path in these energies is long and that final-state interaction of the protons cannot explain the experimental results.[33]

Recently Brown et al.[26] suggested that double-delta formation in the intermediate state of pion absorption, $\pi + N \rightarrow \Delta N \rightarrow \Delta\Delta$, $\Delta\Delta \rightarrow 2N \rightarrow 4N$ may be an important mechanism for pion absorption on heavy nuclei at and above the Δ-resonance energy region. They pointed out that in a simple SU(4) quark coupling model the transition $N\Delta \rightarrow \Delta\Delta$ is expected to be stronger than the transition $N\Delta \rightarrow NN$. Since with intermediate-energy pions the two excited Δ's are very off-shell, it is likely that they would not decay, but interact with two more nucleons in the nucleus via the $N\Delta \rightarrow NN$ process. This model can naturally explain the fact that more than two nucleons participate in the absorption process and predict a $Y_p(\pi^+)/Y_p(\pi^-)$ ratio in good agreement with the data, as can be seen in Table II. See the schematic description of the double-Δ procedure in Fig. 17(b).

The dominant isospin channel contributing to double-delta excitation is $\pi\,(NN)_{T=1} \rightarrow (\Delta N)_{T=2} \rightarrow (\Delta\Delta)_{T=2}$. This is to be compared with the "conventional" two-body process, which proceeds mainly via $\pi\,(NN)_{T=0} \rightarrow (\Delta N)_{T=1} \rightarrow (NN)_{T=1}$, as we discussed in the previous section.

I would like to point out that absorption via a single $\Delta N \rightarrow NN$ transition preceded by multiple scattering of the pion with the formation of additional Δ resonances, as shown schematically in Fig. 17(a), can also explain the experimental information. The difference between this mechanism and that proposed by Brown et al. is that they suggest that the process takes place through the formation of a Δ-Δ intermediate state (two

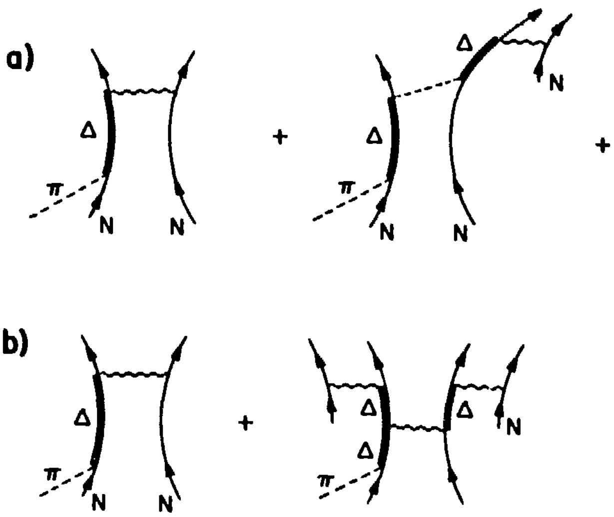

Fig. 17. (a) Absorption through sequential formation and decay of Δ isobars. (b) Absorption through formation of a ΔΔ state.[26]

Δ resonances exist simultaneously in the nucleus), whereas the other mechanism assumes sequential formation of two or more Δ resonances.

In a recent paper[23] Fraenkel, Kalbermann, Clover, and myself compared the predictions of the intranuclear cascade (INC) model for pion-nucleus reactions with the experimental results for inclusive inelastic scattering, true absorption, and angular correlations for the $(\pi,\pi p)$ and $(\pi^+,2p)$ processes. In general, good agreement was obtained between the predictions of the model and the experimental results.

In this work[23] the probability distribution for pion absorption as a function of the number of Δ resonances formed during this process was calculated and is shown in Fig. 18. The calculated distribution is quite broad, approximately angle independent, and shows a large probability for the creation of one to three Δ resonances (i.e., two to four participating nucleons) in the absorption. These results are in good agreement with the observed number of nucleons[15] as well as with the optical-model calculation of Matusani and Yasaki[24] for 240-MeV pion absorption on ^{16}O, and transport calculation by Girija and Kaltun.[25]

We show in Table II the ratio R of proton emission in the 220-MeV pion absorption on ^{27}Al, ^{58}Ni, and ^{181}Ta, together with the experimental results of McKeown et al.[15] and the calculated results of Brown et al.,[26] based on the Δ-Δ model. It is seen that the results, which assume pion absorption

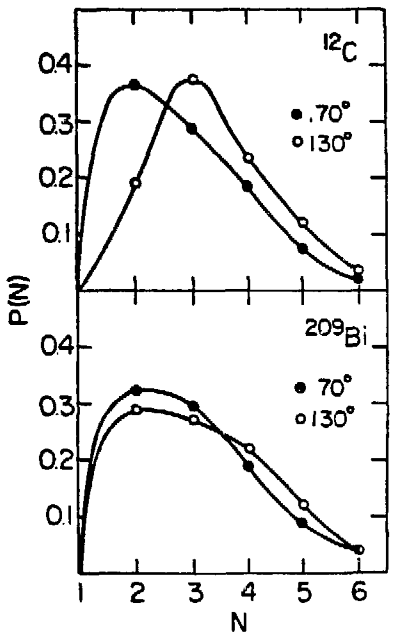

Fig. 18. The probability distribution for the inclusive (π^+,2p) reaction for 245-MeV π^+ on ^{12}C and ^{209}Bi as a function of the number of nucleons N that interact with the pion for two angles of one of the emitted protons, $\theta_p = 70^\circ$ (full circles) and $\theta_p = 130^\circ$ (open circles).

TABLE II. Ratio of proton yield from π^+ or π^- absorption on three different nuclei, following from the double-Δ mechanism prediction (Ref. 26), experimental data (Ref. 15), and INC calculation (Ref. 23). The incoming pion energy is 220 MeV. Only protons above 40 MeV were measured in the experiment[a] and were considered in the INC calculation.[b]

$\frac{Y_p(\pi^+)}{Y_p(\pi^-)}$	Experiment[a]	ΔΔ Mechanism[c]	INC Calculation[b]
^{27}Al	3.8 ± 0.8	4.1	4.0
^{58}Ni	3.7 ± 0.7	4.2	3.6
^{181}Ta	3.4 ± 0.6	3.9	3.4

[a]Ref. 15.
[b]Ref. 23.
[c]Ref. 26.

to proceed through a single ΔN intermediate state but allow pion scattering with Δ formation prior to absorption, reproduce the experimental results equally well. The agreement of the INC calculation with the measured angular correlation in the coincidence experiment[34] is demonstrated in Fig. 19.

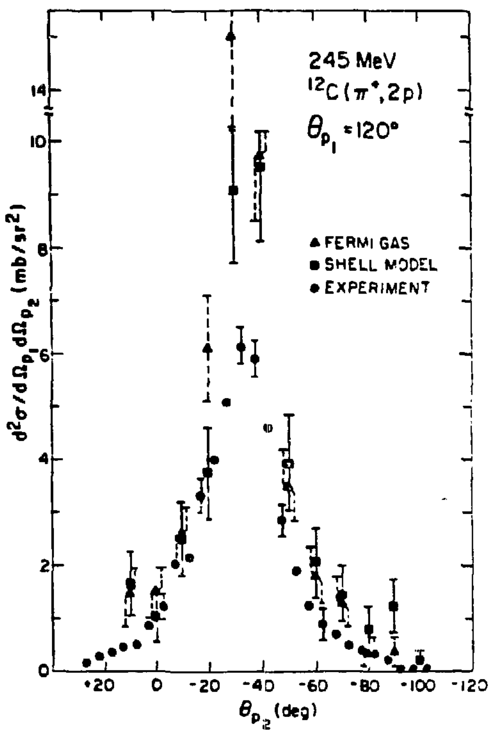

Fig. 19. Proton-proton angular correlation for the inclusive $(\pi^+,2p)$ reaction on ^{12}C at a pion bombarding energy of 245 MeV. The first proton is detected at an angle of 120°. The circles denote the experimental results of Altman et al. (Ref. 34), the squares denote the calculated results with the shell-model harmonic-oscillator wave-function momentum distribution, and the triangles denote the calculated results for the degenerate Fermi gas momentum distribution (see details in Ref. 23).

In summary, I think that the experimental data discussed do not necessarily imply that double-Δ excitation is the dominant pion-absorption mechanism, since these experimental features can also be explained by sequential rather than simultaneous Δ formation prior to absorption. However, I wish to emphasize that I do not claim that the Δ-Δ mechanism is negligible, only that the experimental data cited by Brown et al. do not uniquely imply it. In order to determine the relative importance of the Δ-Δ absorption mechanism compared to the "conventional" single-Δ process, more experimental information as well as more elaborate calculations of the total absorption cross section and its energy and target dependence, are needed. More restricted experimental information on this process can be obtained by multinuclei detection following pion absorption[35] or by study of the Δ-Δ intermediate-state contribution to the (π,2π) reaction, a possibility we intend to discuss in the next section.

B. The NΔ → ΔΔ Transition and Pion Production

In the process of πNN → NΔ → ΔΔ the incident pion energy is, on the average, distributed equally to each one of the intermediate Δ's. If the incident pion has energy of the order of the Δ resonance and two Δ's are excited, they are off shell and the Δ → πN decay is kinematically suppressed. In this case it is most likely that both Δ's will deexcite via the ΔN → NN process, as discussed in the previous section. If the incident pion energy increases, more phase space is available for the Δ decay and the same double-Δ excitation can be expected to contribute to the pion-induced pion-production (π,2π) process (see Fig. 20). The best energy region to look for the NΔ → ΔΔ contributions to pion production is probably T_π = 300-500 MeV. Below this region the pion has too little energy to produce two Δ decays and above this energy region the pion-induced pion production is dominated by the excitation of the T = 1/2 and T = 3/2 baryon resonances.

A first experiment[36] of this kind was recently performed at LAMPF. The reactions $\pi^- d \rightarrow \pi^+\pi^- nn$ and $\pi^+ d \rightarrow \pi^-\pi^+ pp$ were studied by detecting pions of charge opposite to the incident beam. Since double-charge exchange is impossible on the deuteron, the detection of a pion with a charge opposite to the incident one is an unambiguous identification of the pion-production process.

Pion production on the deuteron (a T = 0 nucleon pair) is in the case of the double-Δ process down by a factor of 1/3 compared to the most favorite channel $\pi\,(NN)_{T=1} \rightarrow (N\Delta)_{T=2} \rightarrow (\Delta\Delta)_{T=2}$. Moreover, since the deuteron is a diluted system, this reaction probes mainly the long-ranged interaction

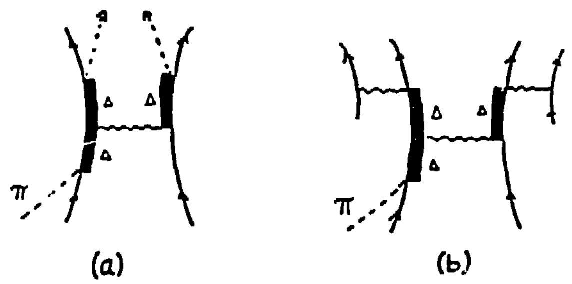

Fig. 20. (a) Pion-induced pion production via Δ-Δ intermediate state. (b) Pion true absorption via Δ-Δ intermediate state.

between the Δ and N. However, the deuteron is the simplest nucleus in which two-nucleon mechanisms, even if weak, can exist. Since it is a loosely bound system, one may expect that the free $\pi N \to \pi\pi N$ amplitude will be only little affected by the second nucleon. Moreover, the deuteron wave function is well determined up to very high momentum from electron- and proton-scattering experiments. Thus the ingredients for reliable calculations of the quasi-free process are available, and a comparison between the $\pi^-d \to \pi^+\pi^-nn$ and $\pi^+d \to \pi^-\pi^+pp$ data and the quasi-free prediction would yield information on two-nucleon production mechanisms.

Figures 21-23 show the double differential cross sections for the $\pi^-d \to \pi^+\pi^-nn$ and $\pi^+d \to \pi^-\pi^+pp$ reactions at 256, 331, and 450 MeV. Interpretation of these data is aided by comparison with two simple models of the reaction. The solid curves represent the distribution of events in the four-body phase space, normalized so that the distribution integrated over energy and angle will equal the integrated-reaction cross section determined from the data.

The dashed curves are the predictions of a calculation based on plane-wave approximation of quasi-free pion production on one nucleon with the use of a phenomenological on-shell amplitude deduced from the $\pi^-p \to \pi^+\pi^-n$ data.[37] Once this production amplitude is chosen, the quasi-free calculation involves no other free parameters. The quasi-free calculations are in surprisingly good agreement with the general features of the data, although some discrepancies do exist. At 256 MeV the quasi-free calculation reproduces the shape of the spectra very well, but the calculated total cross section is 20% below the measured result. The dotted curve in Fig. 21 is the quasi-free calculation normalized by the ratio of the measured and the calculated integrated cross sections. At 331 MeV both the shape and the integrated-reaction cross section obtained from the quasi-free calculation agree with the measurement within the experimental uncertainty. At 450 MeV there are some slight discrepancies between the calculated quasi-free process and the data at backward angles.

At this point the recent results from this experiment are waiting for theoretical interpretation in terms of double-Δ excitation. Are they consistent with what one can expect from double-Δ mechanisms?

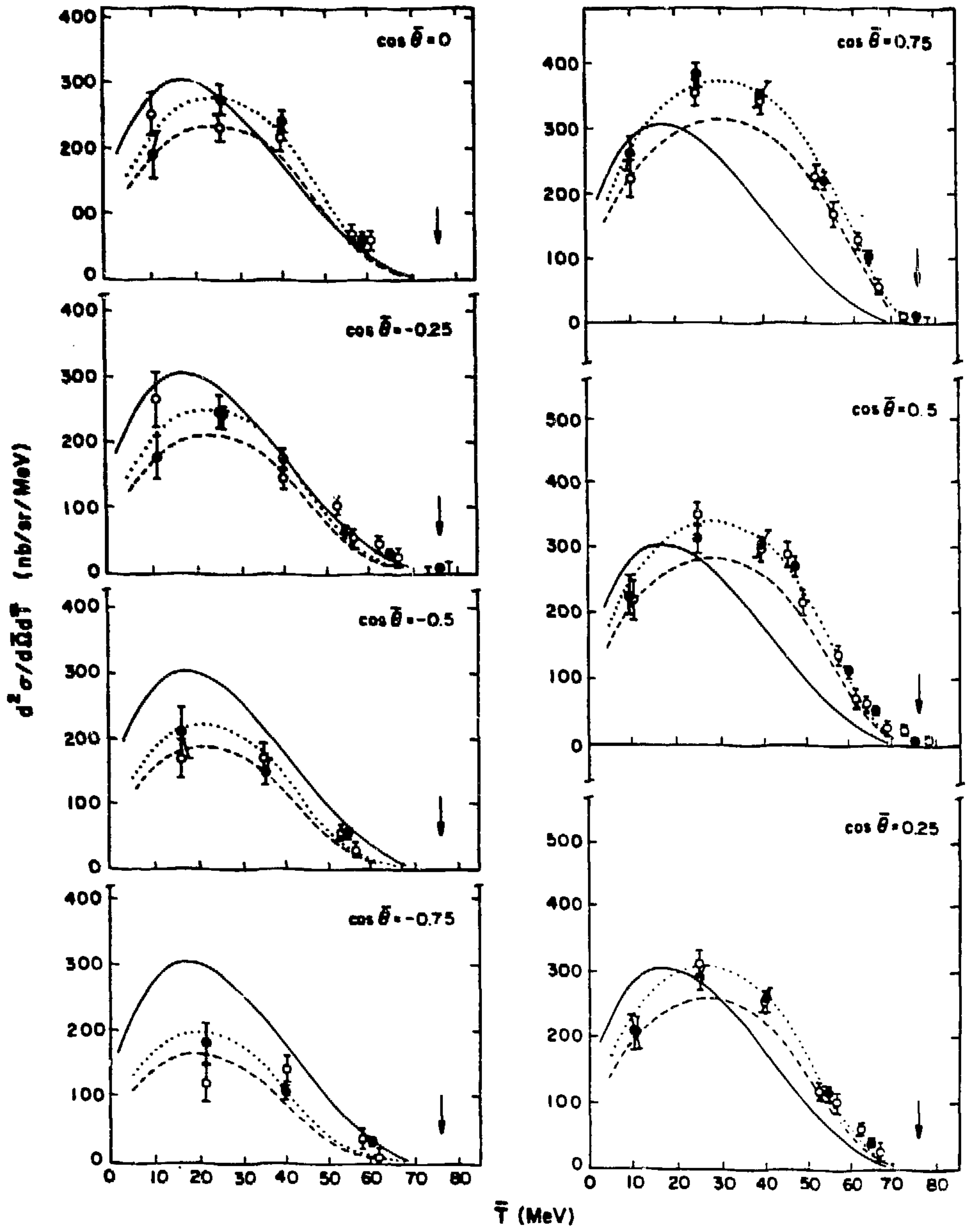

Fig. 21. Doubly differential cross section for the $\pi^- d \to \pi^+\pi^- nn$ ($\pi^+ d \to \pi^-\pi^+ pp$) reactions at 256 MeV. $\bar{T}$ and $\bar{\theta}$ are the outgoing π^+ (π^-) kinetic energy and angle in the center-of-mass system of the incident pion and deuteron. The arrows mark the energy corresponding to the two-body $\pi(\pi NN)$ production with zero binding energy for the πNN system. The solid curves represent four-body phase space normalized to the data. The dashed and dotted lines are quasi-free calculations in plane-wave approximations (see text and Ref. 36).

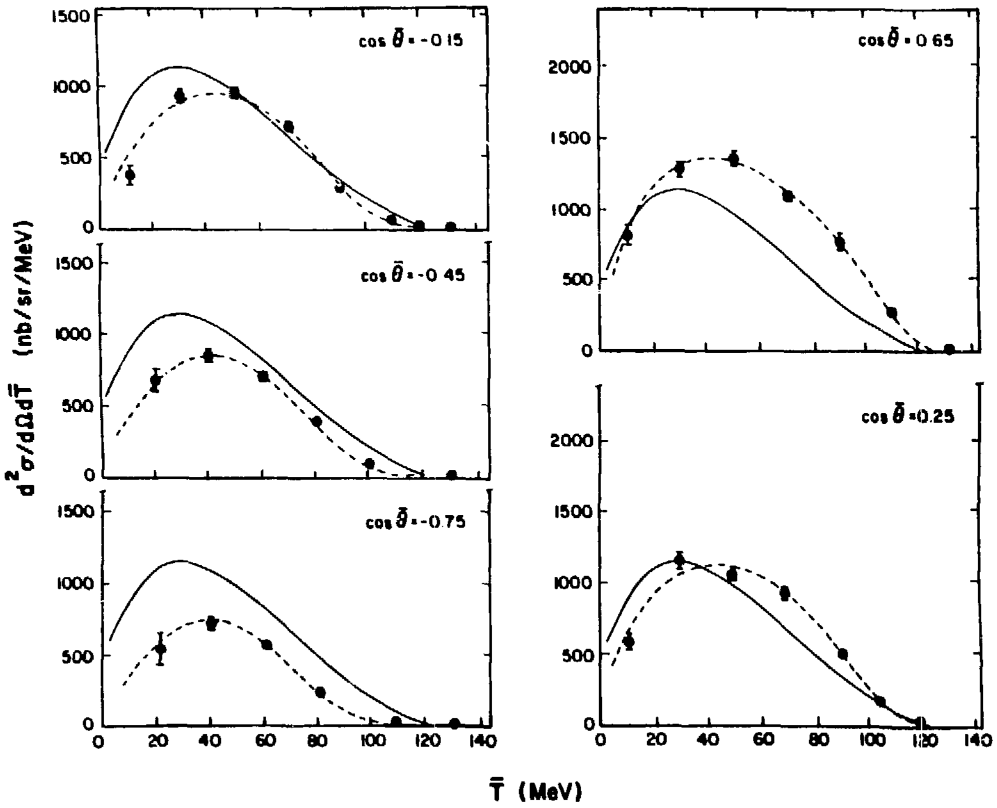

Fig. 22. Same as Fig. 21, but for T_{π}^{in} = 331 MeV.

In parallel to the theoretical work that we hope this measurement will initiate, we intend to measure[38] the pion-induced pion production on ^3He (π^+ $^3He \rightarrow \pi^-$ X) with the same experimental technique and study the production on T = 1 nucleon pair and the short-range forces. On heavy nuclei a coincidence experiment is required to identify unambiguously the (π,2π) reaction. In this case the signal for double-Δ production is an increase in the $(\pi^+,2\pi^+)/(\pi^+,\pi^+\pi^-)$ ratio. An approved proposal at LAMPF will pursue this point.[39]

IV. SUMMARY

The Δ resonance plays an important role in many areas of medium-energy and low-energy nuclear physics. It dominates the pion-nucleus reactions and affects other hadron-nucleus, electron-nucleus, and photonuclear reactions. The question of how the Δ interacts with the nucleus and with nucleons in the nucleus is therefore important for understanding all these processes. Moreover, it is a good example of studying the more general

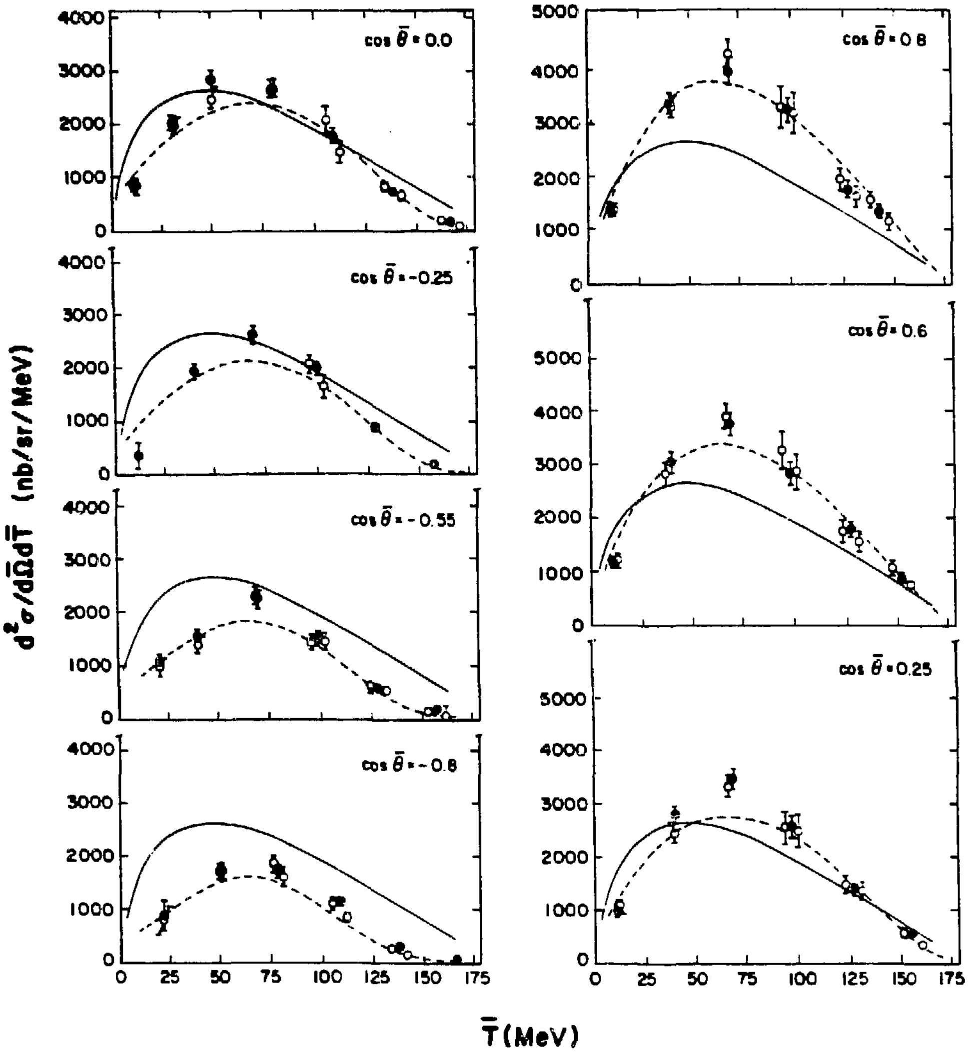

Fig. 23. Same as Fig. 21, but for T_{π}^{in} = 450 MeV.

topic of the strong interaction between a resonance and other hadrons. The experimental study of pion-nucleus reactions provides an opportunity to examine this question. We begin to have experimental information on Δ decay, Δ propagation, and Δ-N interaction in nuclei. Recent experimental studies of pion true absorption, quasi-free nucleon knockout reactions, and pion-induced pion production were presented and discussed in the context of their contribution to the microscopic understanding of the Δ-N interaction.

Due to time limitation, I had to skip a few topics that are strongly related to this subject. To make a more complete picture, I refer the interested reader to these topics. In this talk I emphasized the experiments related to the microscopic understanding of the Δ-N interaction. There is a phenomenological description of the Δ-N interaction in terms of optical potentials in the framework of the isobar-hole model[40] or the unified theory of pion-elastic single- and double-charge-exchange scattering.[41] Of special interest is the study of the spreading potential in the isobar-hole-model approach. Another topic omitted is the importance of the Δ dynamics to the understanding of the double-charge-exchange reaction. The reader can refer to Ref. 42 for more details on this subject.

REFERENCES

1. J. Arends et al., Bonn preprint (1982).

2. J. H. Koch and E. J. Moniz, Phys. Rev. C 20, 235 (1979).

3. J. Mongey et al., Phys. Rev. Lett. 41, 1645 (1978).

4. J. Schiffer, submitted to Comments on Nucl. Part. Phys.

5. A compilation of the experimental results for $\pi d \rightarrow 2p$ reaction is given in an invited talk by D. Ashery, in the Proc. of the Symposium on Delta-Nucleus Dynamics, Argonne National Laboratory document ANL-PHY-83-1 (1983), p. 23 (unpublished).

6. D. Ashery et al., Phys. Rev. Lett. 47, 895 (1981); and contribution E-20 to the Tenth Int. Conf. on Particles and Nuclei, Heidelberg, West Germany, August 1984.

7. M. A. Moinester et al., Phys. Rev. Lett. 52, 1203 (1984); K. Aniol et al., contribution E-17 to the Tenth Int. Conf. on Particles and Nuclei, Heidelberg, West Germany, August 1984; and A. Altman et al., contribution E-19.

8. G. Backenstoss et al., Phys. Lett. 137B, 329 (1984); and contribution E-16 to the Tenth Int. conf. on Particles and Nuclei, Heidelberg, West Germany, August 1984.

9. D. Gotta et al., Phys. Lett. 112B, 129 (1982).

10. T. S. H. Lee and K. Ohta, Phys. Rev. Lett. 49, 1079 (1982).

11. H. Toki and H. Sarafian, Phys. Lett. 119B, 285 (1982).

12. R. R. Silbar and E. Piasetzky, Phys. Rev. C 29, 1116 (1984).

13. G. Miller, E. Piasetzky, and D. Ashery, in preparation.

14. The exact definition of the quasi-free cross section and the analysis of the experimental results that led to this conclusion can be found in A. Altman et al., Phys. Rev. Lett. 50, 1187 (1983).

15. R. D. McKeown et al., Phys. Rev. Lett. 44, 1033 (1980); and Phys. Rev. C 24, 211 (1981).

16. E. Piasetzky et al., Phys. Rev. Lett. 46, 1161 (1981); Phys. Rev. C 25, 2687 (1982); and Phys. Rev. C 26, 2702 (1982).

17. I. Navon et al., Phys. Lett. 95B, 365 (1980).

18. D. Ashery et al., Phys. Rev. Lett. 50, 482 (1983).

19. A. Altman et al., Phys. Rev. Lett. 50, 1187 (1983); A. Altman et al., to be published.

20. SIN Proposal R-83-28, G. S. Kyle and A. Altman, cospokesmen.

21. TRIUMF Proposal 255, A. Altman, spokesman.

22. C. E. Stronach et al., Phys. Rev. C 23, 2150 (1981).

23. Z. Fraenkel, E. Piasetzky, and G. Kalbermann, Phys. Rev. C 26, 1618 (1982); and Z. Fraenkel, E. Piasetzky, and M. R. Clover, Phys. Rev. C 30, 720 (1984).

24. Masutani and Yazaki, Phys. Lett. 104B, 1 (1981).

25. V. Girija and D. S. Koltun, Phys. Rev. Lett. 52, 1397 (1984).

26. G. E. Brown, H. Toki, W. Weise, and A. Wirzba, Phys. Lett. 118B, 39 (1982).

27. C. H. Q. Ingram et al....

28. M. Thies, Nucl. Phys. A382, 434 (1982).

29. G. S. Kyle et al., Phys. Rev. Lett. 52, 974 (1984).

30. M. Hirata, F. Lenz, and M. Thies, Phys. Rev. C 28, 785 (1983).

31. F. Lenz, private communication.

32. LAMPF Proposal 776, S. Gilad and E. Piasetzky, cospokesmen.

33. R. D. McKeown et al., Phys. Rev. Lett. 45, 2015 (1980).

34. The data that are compared with the calculations are results of analysis with slightly different cuts than finally were published by A. Altman et al. (Ref. 19). The calculation and the data were obtained with the same cuts.

35. An experiment like this will be possible with a 4π detector that is under consideration in a few laboratories.

36. E. Piasetzky et al., Phys. Rev. Lett. 53, 540 (1984); and J. Lichtenstadt et al., Phys. Rev. C (in preparation).

37. C. W. Bjork et al., Phys. Rev. Lett. 44, 62 (1980).

38. LAMPF Proposal 820, E. Piasetzky, P. A. M. Gram, G. Rebka, and J. Lichtenstadt, cospokesmen.

39. LAMPF Proposal 734, E. Piasetzky, N. DiGiacomo, and J. Lichtenstadt, cospokesmen.

40. M. Hirata, J. H. Koch, F. Lenz, E. J. Moniz, Ann. Phys. 120, 205 (1979); M. Hirata, F. Lenz, and K. Yazaki, Ann. Phys. (NY) 108, 116 (1977); F. Lenz and E. J. Moniz, Comm. Nucl. Part. Phys. 9 (4), 101 (1980); and references quoted in these papers.

41. M. B. Johnson, Proc. Symp. on Delta-Nucleus Dynamics, Argonne National Laboratory document ANL-PHY-83-1 (1983), p. 153 (unpublished).

42. M. B. Johnson et al., Phys. Rev. Lett. 52, 593 (1984) and references quoted therein.

MEASUREMENT OF PARITY NONCONSERVATION IN THE PROTON-PROTON TOTAL CROSS SECTION AT 800 MeV

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ABSTRACT

We report a measurement of parity nonconservation in the scattering of 800 MeV (1.5 GeV/c) polarized protons from an unpolarized liquid hydrogen target. The experiment was a transmission measurement. Corrections to the measured transmission were made for contributions from systematic changes in beam properties. The result for the longitudinal asymmetry in the total cross section is $A_L = (2.4 \pm 1.1) \times 10^{-7}$.

An experiment has been concluded at LAMPF to search for parity nonconservation in $\vec{p}$-p scattering. The goal of the measurement was to determine the contribution of the strangeness-conserving weak force to nucleon-nucleon scattering at 800 MeV. Although the scattering is dominated by the hadronic interaction, a weak-interaction contribution may be identified by the signature of parity nonconservation.

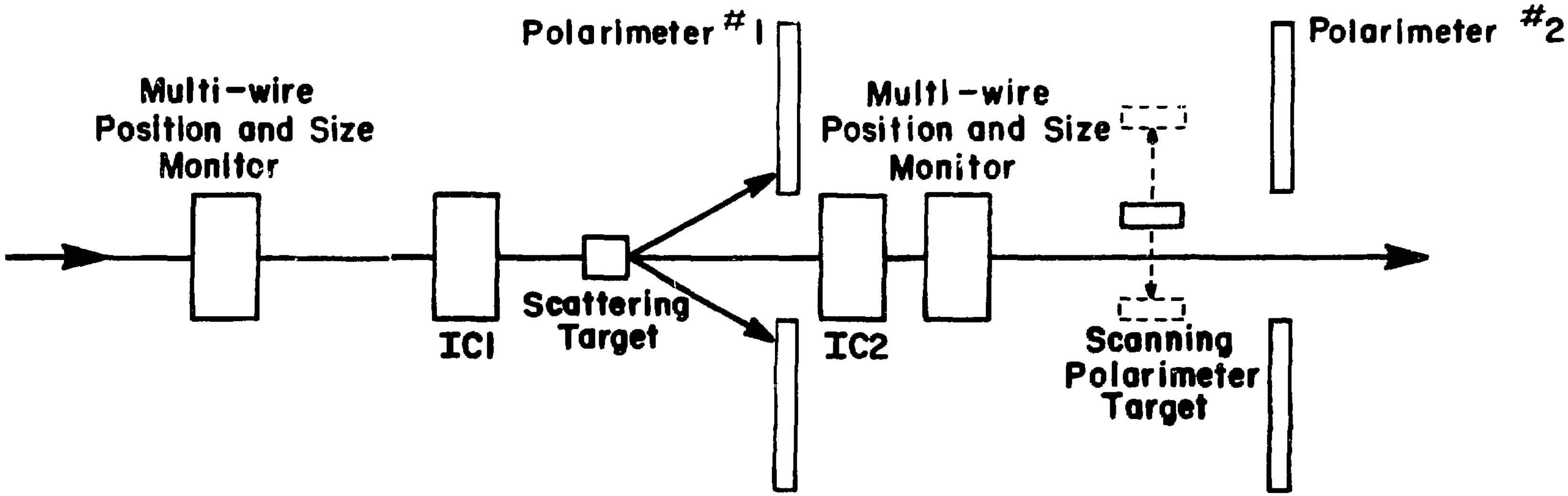
In the experiment, longitudinally polarized protons are scattered from an unpolarized liquid hydrogen target. The helicity of the incoming protons is reversed at 30 Hz, and parity nonconservation is searched for as a small helicity dependence in the total cross section. To characterize such a dependence, a longitudinal asymmetry A_L is defined: $A_L = (\sigma_+ - \sigma_-)/(\sigma_+ + \sigma_-)$ where $\sigma_+(\sigma_-)$ is the total cross section for positive (negative) helicity protons on the target. An A_L resulting from an interference of the strong and the weak scattering amplitudes is expected to have a magnitude at the 10^{-7} level.

Measurements of A_L have been made at other energies. At 15 and 45 MeV, experiments[1-3] on hydrogen yield non-zero results of $A_L = (-1.7 \pm 0.8) \times 10^{-7}$ and $A_L = (-2.3 \pm 0.8) \times 10^{-7}$ respectively, in good agreement with theoretical predictions based on a meson-exchange model[4-6] and a hybrid quark model.[7] In contrast, a high-energy experiment,[8] with 6 GeV/c protons on a water target, has reported a value of $A_L = (2.65 \pm 0.60) \times 10^{-6}$. This value is more than an order of magnitude larger than meson-exchange predictions[9] for N-N scattering. (Nuclear structure effects are not expected to be significant at 6 GeV/c.) Recent theoretical work[10] treating the quark constituents of nucleons has predicted a value of $A_L \sim 2 \times 10^{-6}$ at 6 GeV/c, in good agreement with the high-energy experimental result. Another calculation,[11] involving wave-function renormalization, has predicted a similar result.[12]

The present experiment, at 1.5 GeV/c (800 MeV), is at an energy intermediate to the previous measurements. When extended to this energy, the theoretical models[9,13,14] provide conflicting predictions of $|A_L| < 2 \times 10^{-7}$ and $A_L = 1.2 \times 10^{-6}$. An experimental determination of the asymmetry at 800 MeV gives new information on the energy dependence of A_L and provides important input to further theoretical work.

The experiment was performed utilizing the longitudinally polarized 800 MeV H^- beam of the Los Alamos Meson Physics Facility. A beam of polarized H^- ions was produced in a Lamb-shift-type ion source[15]. H^0 ions were initially polarized in the "spin-filter" region of the source. Downstream of the spin-filter, the polarization was reversed at 30 Hz by a weak magnetic field (10 Gauss) acting on neutral hydrogen atoms. The emerging H^0 ions were converted to H^- ions in passing through an argon-filled gas cell where an additional electron was acquired. The resulting H^- beam, after exiting the source, was accelerated to 800 MeV and reached the apparatus in pulses of 500 μsec duration with a 120 Hz repetition rate. At our experimental beam line, the H^- ions were passed through a stripping foil to remove the electrons and to create the polarized proton beam incident on our apparatus. Beam intensities ranged from 1 to 5 nA. Average polarization was 70%.

The layout of the apparatus is shown in Fig. 1. Situated to either side of a 1-meter long liquid-hydrogen target, two integrating ion chambers (IC1 and IC2) measured the helicity-correlated transmission, $Z = (T_+ - T_-)/(T_+ + T_-)$, of protons through the target. From this value



EXPERIMENTAL APPARATUS

Fig. 1.

Experimental layout. Ion chambers, IC1 and IC2, measure transmission of beam through scattering target. Multi-wire chambers measure beam position and size. Polarimeters determine both average transverse polarization and first moment of transverse polarization.

the helicity-correlated cross section $A_L = Z/(P \ln T)$ can be calculated, where P is the beam polarization and T is the average transmission of the target. For our setup, a P = .7 and T = .85 resulted in a value of $1/(P \ln T)$ of 8.8. Hence to attain a sensitivity in A_L of 1 part in 10^{-7}, a measurement of Z to nearly 1 part in 10^{-8} was necessary.

The statistical sensitivity achievable in the measurement was limited by the beam intensity available and the level of random fluctuations in the measured transmission signal (noise). Because the incident proton energy exceeded the threshold to produce spallation fragments in collisions with nucleii, a large noise level resulted that was overcome only through the development of special spallation-minimizing detectors[16] (Fig. 2).

Another major concern lay with beam systematics: changes in beam properties which, if correlated to the helicity reversal, could result in mimicing a true parity signal. The beam systematics we identify are helicity-correlated changes in position, intensity, size, average residual transverse polarization, and a non-zero 1st moment of transverse polarization across the beam profile (CPOL). A net residual transverse polarization results in an unwanted helicity-dependent contribution if its direction reverses with the longitudinal helicity reversal and if the beam is positioned off of the symmetry axis of the transmission detectors. A CPOL distribution of polarization over the beam profile can result in an unwanted contribution to Z even if the average transverse polarization over the profile is zero.

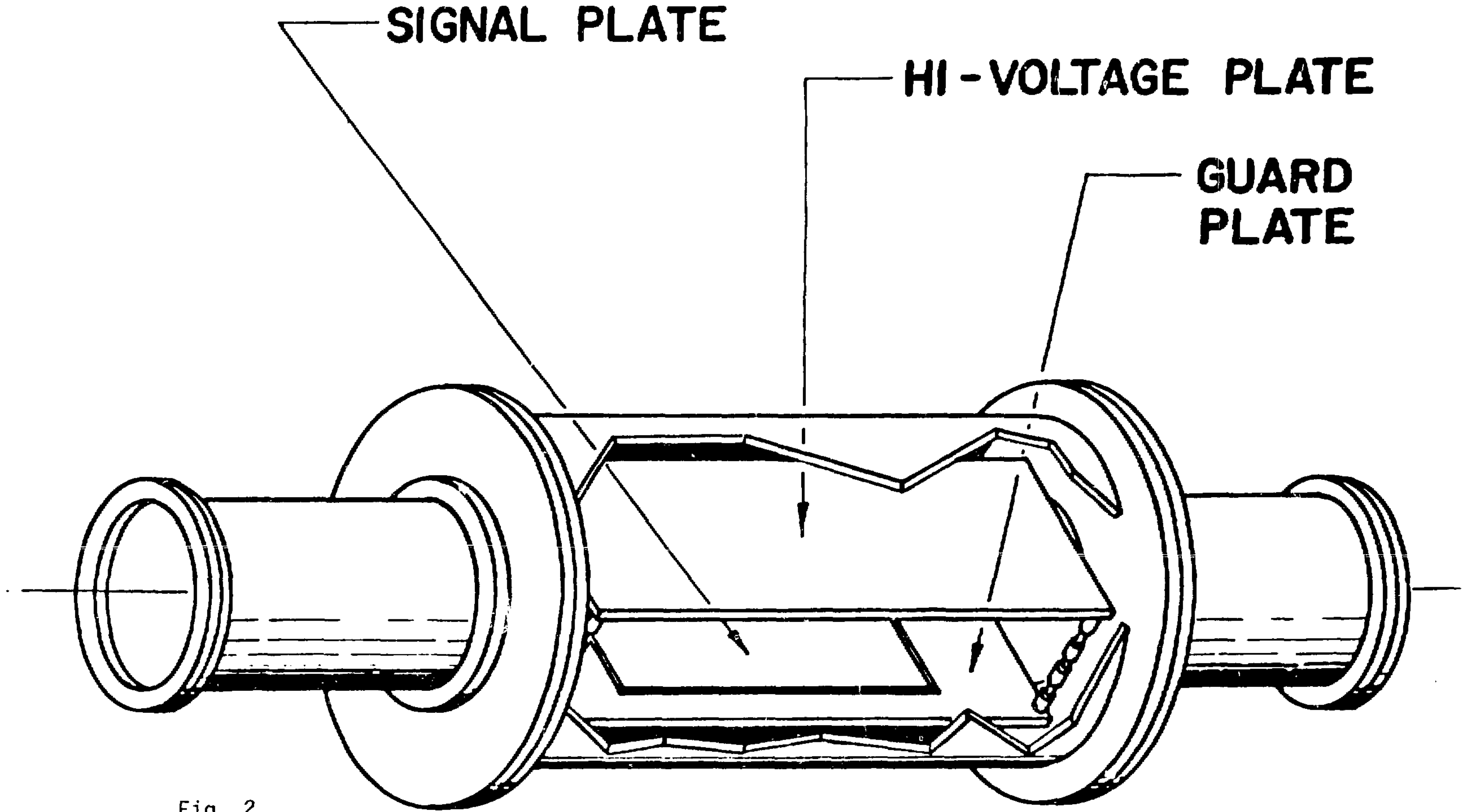


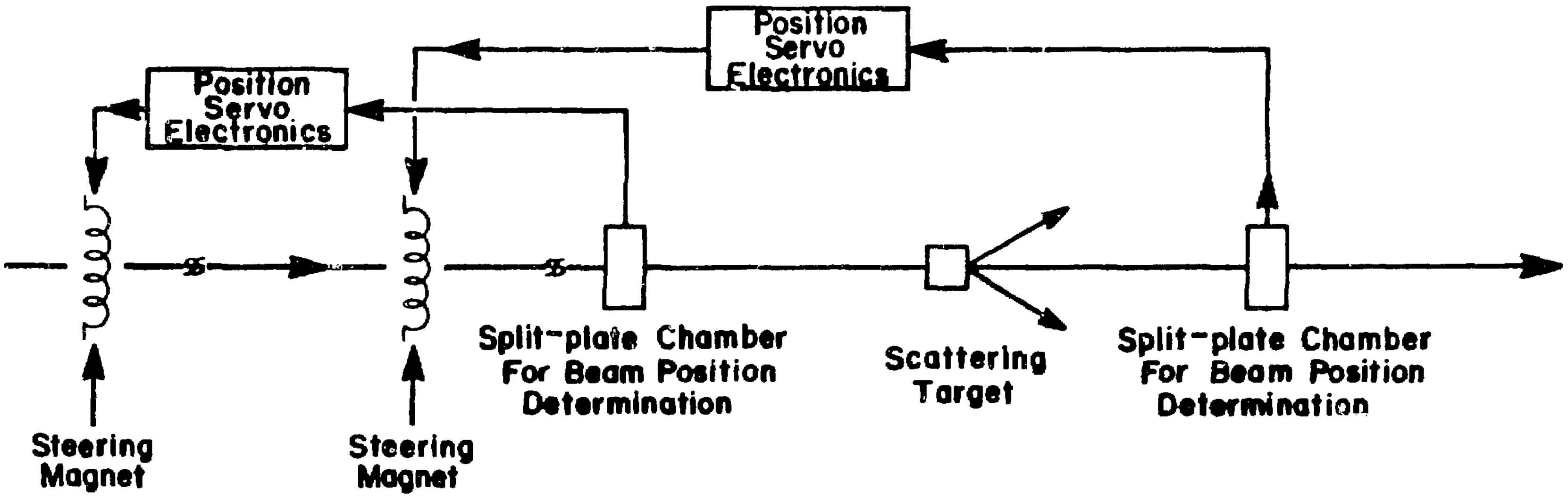
Fig. 2.

Low-noise ion chamber used to measure transmission. Design of chamber features: transverse collection field, hydrogen used as active gas, end windows distant from active volume. Chamber is low-noise because spallation has been minimized.

The placement of detectors used to measure beam systematics is depicted in Fig. 1. The setup is similar to the one used in a previously reported[1] run with an H_2O target. In the LH_2 run, however, improvements allowed a better determination to be made of systematic contributions to Z. Two multi-wire position monitors (MWPM) were added which allowed us, for the first time, to monitor both the size and position of each beam pulse. A four-arm polarimeter used the LH_2 target as an analyzer to measure residual transverse polarization in the beam. A second polarimeter was added with a target that continously scanned the beam profile for a CPOL component. The detectors of both polarimeters were scintillator-photodiode combinations. The upstream ion chamber of the transmission measurement, as before, was used to measure intensity variations.

The feedback loops used to control beam position are shown in Fig. 3. A second servo-feedback loop was added to the single loop used in the H_2O run. In this way we were able to stabilize the beam in angle as well as position. Error signals from both loops were linearly mixed in such a way to maximally decouple one loop from the other. The position sensitive detectors within the loops were mounted on precision translation stages, and beam position at either end of the apparatus could be varied with .1 mm accuracy. A third loop, not shown in the figure, stabilized the beam position on a defining aperture 50 m upstream of the apparatus.

The signal processing chain formed the analog difference of the IC1 and IC2 signals. The difference signal was then amplified, digitized, and integrated over each pulse. To prevent amplifier noise from limiting statistical sensitivity, low current-noise components (.01 pA/$\sqrt{Hz}$) were used in the construction of the current-to-voltage amplification stages,



BEAM POSITION FEEDBACK SERVOS

Fig. 3.

Dual servo-feedback loop utilized in controlling beam position.

whereas low voltage-noise (10 nV/$\sqrt{Hz}$) operational amplifiers were used in the analog-difference and voltage-amplification stages. Amplification of the difference signal prior to digitization prevented round-off error from increasing the noise. Leakage of unwanted 30 Hz electrical pickup (ground loops) into the difference signal was minimized in two ways. First, optical and analog isolators were used in all important signal paths. Second, rather than use a 30-Hz signal to transmit the helicity-reversal information, we used a synchronously-derived 15-Hz digital signal. This 15-Hz signal could later be decoded by computer to reconstruct the timing of the 30-Hz reversal. Electronic pick-up noise was measured to be smaller than detector noise by a factor of 5, and hence was not significant. Other beam-property signals were handled in a similar fashion.

Signals for each beam pulse were written on magnetic tape and analyzed by computer for helicity-correlated variation. Data were analyzed in groups of four beam pulses (quads) to minimize the effects of fluctuations occuring on a longer time scale. The helicity pattern of the group, + - - +, was cnosen to reduce the effects of drifts. Four pulses, rather than two, were included in each quad in order to remove 60-Hz effects. For each quad the quantity $Z = (\overline{T}_+-\overline{T}_-)/(\overline{T}_++\overline{T}_-)$ was calculated. At the end of a run, which consisted typically of 10^5 four-pulse groups, an average was calculated and a statistical uncertainty was computed from the fluctuations of the data.

During the experiment, the contributions of beam systematics were reduced by locating the beam along the symmetry axis of the transmission detectors. Once this axis was determined, the servo-loop system was used to fix the beam position there. We also measured the sensitivity of the transmission, T, to the presence of beam systematics. Subsequently, during the data runs, the presence of each beam systematic was monitored, allowing a correction to Z to be calculated for each systematic.

To minimize contributions from systematics uncorrelated to the beam helicity, the experiment was run for equal time periods in 2 different operating configurations (N and R) of the spin filter in the polarized source. In both configurations protons exiting the source were longitudinally polarized, but the spin directions for the N and R configurations were opposite with respect to the 10-Gauss spin-flip field of the source. Hence, the combination (N-R)/2 cancels the effects of helicity-independent systematics and is referred to as the PNC signal. The combination (N+R)/2 is a measure of helicity-independent systematics and is called the HI signal.

RESULTS

Analyzed results of the experiment are given in Tables I and II. In the analysis the measured transmission for each beam pulse was corrected for the contribution of systematics. Corrections were made for intensity, position, and size. In addition, corrections for net transverse polarization and CPOL were made for each quad and each run respectively. As with CPOL, ground-loop corrections were also made on a run-by-run basis. We discuss the systematic corrections in more detail:

Table I. Contributions of beam systematics to A_L. Both the contributions to PNC (parity nonconserving) and HI (helicity independent) values are given.

Systematic	Contribution to PNC ($\times 10^7$)	HI ($\times 10^7$)
Position	-0.3	2.7
Intensity	0.8	-7.7
Size	-0.1	0.2
Polarization	< 0.1	< 0.1
CPOL	0.1	0.2
Ground loop	0.0	-0.6

Table II. Results for A_L. PNC and HI results are given both before and after corrections for systematics are made.

	($x10^7$) PNC	($x10^7$) HI	χ^2 (# of runs)
Uncorrected	3.0 ± 1.2	-5.0 ± 1.2	300 (152)
Corrected	2.4 ± 1.1	0.2 ± 1.1	159 (152)

INTENSITY

A special apparatus was used to determine the sensitivity Z to intensity modulations. The apparatus consisted of a set of stripper grids that could be moved in and out of the H^- beam path synchronously to the 30-Hz helicity reversal. An H^- ion traversing one of the grids would have a 10% chance of being stripped of its electrons. Positively charged protons that remained in the beam after the stripping process were deflected from the final beam reaching our experimental hall. Hence, the grids produced a 10% modulation of beam intensity synchronous to the helicity reversal.

Data utilizing the stripper grids were taken as the DC intensity and size of the beam were varied. An analysis of these runs indicates a dependence: $dZ/dI = A_0 + A_1 I + A_2 I^2 + A_3/\sigma_x + A_4\sigma_y/\sigma_x$, where I is the beam intensity and $\sigma_x(\sigma_y)$ is the width of the incoming beam in the horizontal(vertical) direction. The first three terms contributing to dZ/dI most likely results from nonlinearities in the detectors and electronics; the last two terms are consistent with recombination effects within the chambers.

POLARIZATION

During the experiment, contributions from polarization systematics were minimized by locating the beam along the polarization symmetry-axis (PSA) of the transmission detectors. To determine this axis, the transverse polarization was deliberately exaggerated, and the beam was moved (scanned) across IC1 and IC2. The changes in Z, measured during the scan, allowed a determination of both the PSA location and the sensitvity of Z to 30-Hz changes in transverse polarization. Because the data runs to measure Z were taken with the beam positioned on the PSA, transverse polarization gives the smallest of all systematic corrections: a correction to A_L of $< 1 \times 10^{-8}$.

POSITION AND SIZE

At each transmission detector, position scans were performed to measure the sensitivity of Z to position and size changes. All beam positions except the one being scanned were left at their PSA settings. The largest measured sensitivity was $dZ/dy = 1.3 \times 10^{-4}$/mm for vertical motion at the downstream detector. Corrections for size variations were calculated from the quadratic components in the position dependence of Z.

Beam position and size were determined from the profile data of the multi-wire position monitors. Beam profiles at the downstream MWPM were broad ($\sigma = 1.4$ cm) and stable due to multiple scattering in the LH_2 target and upstream detectors. Initial position and size values for the downstream MWPM data were determined from a full χ^2-minimization fit to a beam profile taken at the beginning of the run. An algorithm then calculated subsequent beam position and size by Taylor-expanding around the beginning-of-run value. At the upstream MWPM, the narrowness of the beam (σ = 1 to 3 mm) made use of the algorithm unstable. Therefore a different algorithm based on geometrical estimation was used. In the cases of extremely narrow beam widths (σ < .9 mm), the primary beam profile information resided on only 2 wires, and simultaneous position and size information could not be reliably extracted from the profile. In these cases a correction for correlated 30-Hz size variation was not made. The magnitude of the omitted correction to A_L, determined from the majority of runs where size corrections are valid, is estimated to be $< 5 \times 10^{-8}$ per run.

CPOL

A full scanning-polarimeter target scan took nearly 2 minutes to complete. Therefore it was not possible to determine individual pulse-by-pulse corrections for CPOL. Corrections, instead, were made to each run based on a sum of all the scan data taken during that run.

GROUND LOOPS

Ground-loop contributions were measured in runs taken with the beam off. In these runs a mock signal was digitally introduced to simulate the presence of a 5 nA beam. The correction applied to each data run was calculated by normalizing the measured ground-loop value to the actual beam intensity of the run being corrected.

DISCUSSION OF RESULTS

Table I presents, for the PNC and HI configurations, the corrections made to A_L for each systematic. The largest correction is from 30-Hz intensity modulation. For each of the N and R configurations, systematic-contribution uncertainties to A_L are estimated to be small in comparison to the statistical error in A_L. In addition, systematic corrections to N and R measured values are usually similar in magnitude and sign. Therefore, as a result of common-mode cancellation, the correction-introduced uncertainties in the (N-R)/2 PNC value of A_L are not significant in comparison with statistical error.

There are several indications that our applied corrections to A_L are correct. First, applying the corrections decreases the final error in A_L. Second, scatter plots of uncorrected transmission versus various systematic quantities show large correlations that are removed with application of the corrections. And, third, the χ^2 value for the corrected result shows nearly a factor of 2 improvement over that for the uncorrected result. Finally, as can be seen from Table II, the HI result is consistent with zero.

The preliminary PV result of the analysis is $A_L = (2.4 \pm 1.1) \times 10^{-7}$. The central value presented is of similar magnitude but opposite sign to the low-energy (15-45 MeV) experimental results.[1-3] It also indicates a result an order of magnitude smaller than the 6 GeV/c high-energy H_2O result.[8] The result agrees with predictions from the meson-exchange model.[9] The hybrid-quark model[7] predicts a value $< 1 \times 10^{-8}$, and therefore is in disagreement with our result at the 97% confidence level. The predicted value of the wave-function renormalization model[13] is a factor of 5 larger than our measured value. Finally, the result agrees with the high-energy quark-quark model[10] as extrapolated to 800 MeV,[14] but there remain some questions[14] regarding the validity of the model in this energy range.

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REFERENCES

1. D. E. Nagle et al., in High Energy Physics with Polarized Beams and Targets, edited by G. H. Thomas, AIP Conference Proceedings No. 51, (American Institute of Physics, New York, 1978), p. 224.
2. R. Balzer et al., Phys. Rev. Lett. 44, 699 (1980).
3. M. Simonius, in High Energy Physics with Polarized Beams and Targets, edited by C. Joseph and J. Soffer, Experientia Supplementum No. 38, (International Symposium, Lausanne, 1980), p. 355.
4. V. R. Brown, E. M. Henley, and F. R. Krejs, Phys. Rev. C9, 935 (1974). Note that the asymmetry defined there is $2A_L$ as here defined.
5. M. Simonius, Nucl. Phys. A220, 269 (1974)
6. B. Desplanques, J. F. Donoghue, and B. R. Holstein, Ann. Phys. 124, 449 (1980).
7. L. S. Kisslinger and G. A. Miller, Phys. Rev. C 27, 1602 (1983).
8. N. Lockyer et al., Phys. Rev. Lett. 45, 1821 (1980).
9. E. M. Henley and F. R. Krejs, Phys. Rev. D 11, 605 (1975); T. Oka, Prog. Theo. Phys. 66, 977 (1981); A. Barrosa and D. Tadic, Nucl. Phys. A364, 194 (1981).
10. T. Goldman and D. Preston, Nucl. Phys. B217, 61 (1983).
11. G. Nardulli and G. Preparata, Phys. Lett. 117B, 445 (1982).
12. This calculation is controversial, see J. F. Donoghue and B. R. Holstein, Phys. Lett. 125B, 509 (1983); B. H. McKellar, Phys. Lett. 138B, 6 (1984); and reference 13.
13. G. Nardulli, and G. Preparata, Phys. Lett. 137B, 111 (1984)

14. D. Preston, private communication.

15. J. Mckibben, in Polarization Phenomena in Nuclear Physics, edited by G. G. Ohlsen et al., AIP Conference Proceedings No. 69, (American Institute of Physics, New York, 1980), p. 830.

16. J. D. Bowman et al., Nucl. Inst. Meth. 216, 399 (1983).

17. R. W. Harper et al., submitted to Physical Review D.

QUARKLEI: NUCLEAR PHYSICS FROM QCD

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ABSTRACT

The difficulties posed for nuclear physics by either recognizing or ignoring QCD, are discussed. A QCD model for nuclei is described. A crude approximation is shown to qualitatively reproduce saturation of nuclear binding energies and the EMC effect. The model is applied seriously to small nuclei, and to hypernuclei.

I. INTRODUCTION

Since 1973, nuclear physics, meaning the study of nuclei in terms of off-shell nucleons and possibly meson exchanges, has been intellectually untenable. Despite appearances, this may be a generous statement, since it could be argued that the critical time was 1963, when quarks were established, at least for some. I choose 1973 because the strong force, QCD, was theoretically determined at that time. Certainly 10 years later, the point should be understood.

Let me make the problem clear. For a moment, we will ignore the difficulty of understanding off-shell composite states of nucleons and mesons, despite the fact that no one knows how to do this. (Feynman is reputed to have asked: What the hell is an off-shell pion?) Start with conventional point nucleons in nuclear orbitals, and add form factors. But how can we add form factors without producing a physical extent in coordinate space? Having done that, we must address the question of how nucleons may pass through one another without affecting the internal constituents. It is not sufficient that the nucleons are in orthogonal eigenmodes, as their constituents are not, for the point nucleon Hamiltonian.

Aha! you may say. The nucleons do not pass through each other! The wounds in a Brueckner-Hartree-Fock (BHF) picture are similar to what appears in a hard sphere picture. But as they roil around, with their surfaces in close contact at nuclear densities, the question is still, how could these nucleons possibly avoid affecting each other's internal structure. When that structure was a cloud of off-shell pions, the effect was just what was involved to produce binding. But when that structure is a triplet of quarks, the situation looks different.

In fact, things are still very similar. Consider the analogy in chemistry. We do not describe molecular bonding in terms of photon exchanges between point atoms. Instead, despite the good approximations of electronegativity and electron affinities, we understand that the binding comes from a quantum mechanical sharing of electron wave functions. So it seems natural now to think of nuclear binding as due to a similar sharing of quark wavefunctions in a nucleus.

Thus at last, we come to the problem. It is not why we use point nucleons and mesons, plus form-factoring to calculate nuclear properties. The problem is why, in the light of the known composite structure of nucleons in terms of completely different degrees of freedom, does the conventional picture work so very well? I hope to convince you that the answer does lie in the known properties of QCD.

II. NUCLEAR PHYSICS AS AN ASPECT OF QCD

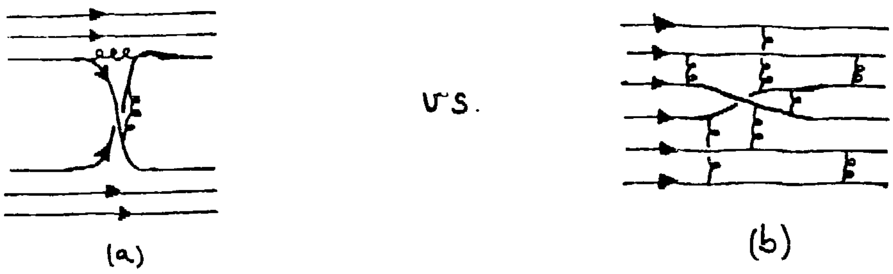
QCD is described by a path integral over quark and gluon fields. To obtain information, we introduce sources and take functional derivatives of the source-dependent path integral with respect to them, in order to obtain quark-quark correlation functions. If we take the 6A-th derivative with respect to 3A quark and 3A antiquark sources, we are studying the propagation of a system with baryon number A. This includes A nucleons propagating freely and independently, two nucleons scattering and A-2 moving freely, ... , and A nucleons scattering simultaneously. The resonance and bound state poles in each scattering subsystem describe nuclei and their excited states.

$$Z[\eta,\bar{\eta}] = \int d[q]d[\bar{q}]d[G]\exp\left\{-iS[q,\bar{q},G] + \int d^4x\,(\bar{q}\,\eta + \bar{\eta}\,q)\right\}$$

When the nucleons are far apart, it is clear that their internal wavefunctions are those of isolated nucleons. When all 3A quarks are in a small region, on the order of the appropriate nuclear size, the gluons summed over in the path integral connect all of the quark lines. Further, no quark is required, even by confinement, to travel near a particular pair of quarks. Thus we cannot identify which quarks make up which nucleon. At this level, QCD offers no hope of describing a nucleus as any kind of a collection of nucleons. A clear molecular analog occurs in the benzene ring: Electrons are so delocalized that it makes no sense to think of even a fraction of an electron shifted between two atoms; they belong to the ring as a whole.

So how can we recover the conventional picture of nuclear physics as an approximation? Let us look at one boson exchange in the quark picture. The leading contribution comes from exchanging a pair of valence quarks between two nucleons. If we look in the t-channel (exchange channel) it is clear that the amplitude can be dominated by resonances between the quark and antiquark. (If we move in the direction of one of the quarks, the quark going the other way appears as an antiquark because, with all of this occuring on a space-like hypersurface, we are effectively moving in a "time-reversed" direction for it.) At large separations between the two nucleons, the dominant resonance will be a pion. At shorter distances, other bosons can contribute, but so can non-resonant processes. The numerical question is whether this breakdown occurs at internucleon separations corresponding to densities greater or less than nuclear matter densities.

Fig. 1 Six quark interaction at a) large, b) small distances



Still, even qualitatively, we can begin to see why one-boson exchange models have a chance to work, and yet cannot be exact. For from the extra gluonic effects (non-resonant corrections) it is clear that the free space couplings of bosons to nucleons should not be the correct values to use in nuclei, and that they should vary with A. So the question becomes: Can we find a better approximation which shows where, and by how much, this one fails?

III. ELEMENTS OF THE QUARK MODEL OF NUCLEI

We believe that we know that if a finite number of quarks are randomly introduced at low density into a compact region, then confinement will require them to form color singlet triples, locally. Any model we introduce should include this property. To make the model tractable, we may indirectly impose this by means of an ansatz, as in the BCS theory of superconductivity, or as a lattice is introduced in solid state theories. Our guide is to incorporate the critical features of BHF nuclei, reinterpreted in quark terms. We take these critical elements to be that the average quark density saturates at a constant volume per quark, and that the quark density is both large in a fractional subvolume, and small in other regions.

We go beyond BHF in allowing a strong phase correlation between quark amplitudes in different regions of the same nucleus. BHF assumes that there are no such phase correlations between quarks in different nucleons. We can see that this is unreasonable on general quantum mechanical grounds. Consider two localized wave packets that are widely separated, representing the same color and flavor of quark in two nucleons. The sum and difference of these wave functions are the correct symmetry preserving combinations to construct, but this will be irrelevant for large separations as the eigenenergies are degenerate. However, when the two packets are near each other, nonlinear interactions in the overlap region will in general split the degeneracy. The properly symmetrized wavefunctions, complete with phase correlations across the region between the maxima of the envelopes, will then form the proper, nondegenerate eigenmodes of the system.

G.J. Stephenson, Jr. and I have attempted to incorporate these features by assuming that the QCD path integral is dominated by a mean field of gluonic excitation which produces a multi-welled color electric potential within which the single-particle quark wavefunctions develop.[1] We take these wells to be the QCD potential measured between quarks and antiquarks in high energy (charmonium and upsilonium) experiments. For convenience, we will often take this potential to be linear in the radial distance from the origin of the well, which is a good approximation to the high energy results.[2] There is one such well for every three quarks (one "nucleon"). Later, I will describe how we determine the relative location of the centers of the wells in a self-consistent manner. For now, just imagine that they form some fixed array.

Where the values of these linearly rising potentials are equal, at the equidistant points between centers, we truncate the potentials. Thus, the potential seen by a quark continues to rise only at the nuclear surface. In this, we are assuming that, as in the work function for metals, the difficulty of separating a quark from a nucleus is not significantly greater than that required to separate it from an individual nucleon. The result is an average potential, similar in spirit to the conventional nuclear average potential, but more complicated in structure due to the confining effects of QCD.

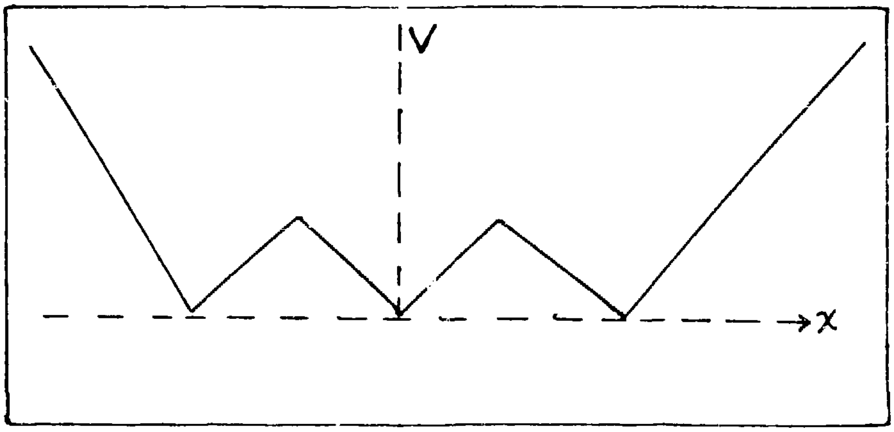


Fig. 2 Nuclear potential in coordinate space.

The question now arises: Does filling the quark eigenmodes of this potential, in a "quark shell model", produce anything that looks like real nuclei? A real calculation requires further that we project out states of good spin and parity. The full calculation is still in progress. In what follows, I shall first show you a crude calculation of the binding energy per nucleon in a kind of infinite nuclear matter which gives enough credence to the idea to warrant further effort. I will then indicate how this picture naturally produces the EMC effect[3], and indicate our progress on a realistic calculation of Helium-4. Finally, I will describe how hypernuclei can provide tests of the predictive power of our picture of nuclei.

IV. CUBICAL NUCLEONS AND CUBICAL NUCLEI

To make the problem simple, we start from the Dirac equation for massless quarks, with a scalar QCD potential. This eliminates Klein paradox problems. The next step is to assume that the Dirac wavefunction has the form of the conjugate Dirac operator acting on a spinor which has the lower pair of components identical, up to an overall sign possibly, to the upper pair of components. This was introduced some time ago by Feynman and Gell-Mann[4] for vector potentials. Here, it is not consistent unless the spin orbit term is negligible; i.e. - unless the gradient of the scalar potential dotted into the Pauli matrices annihilates the upper (or equivalently lower) two components. We chose to do this and ignore spin-orbit effects as the result is a Schroedinger-like equation with energy-squared eigenvalues. This is similar to what could be obtained by non-relativistic reduction, without the cost of making the incorrect assumption that the system is non-relativistic. I emphasize that this is done for convenience and simplicity, and that there is no problem in applying the exact Dirac equation to the actual problem.

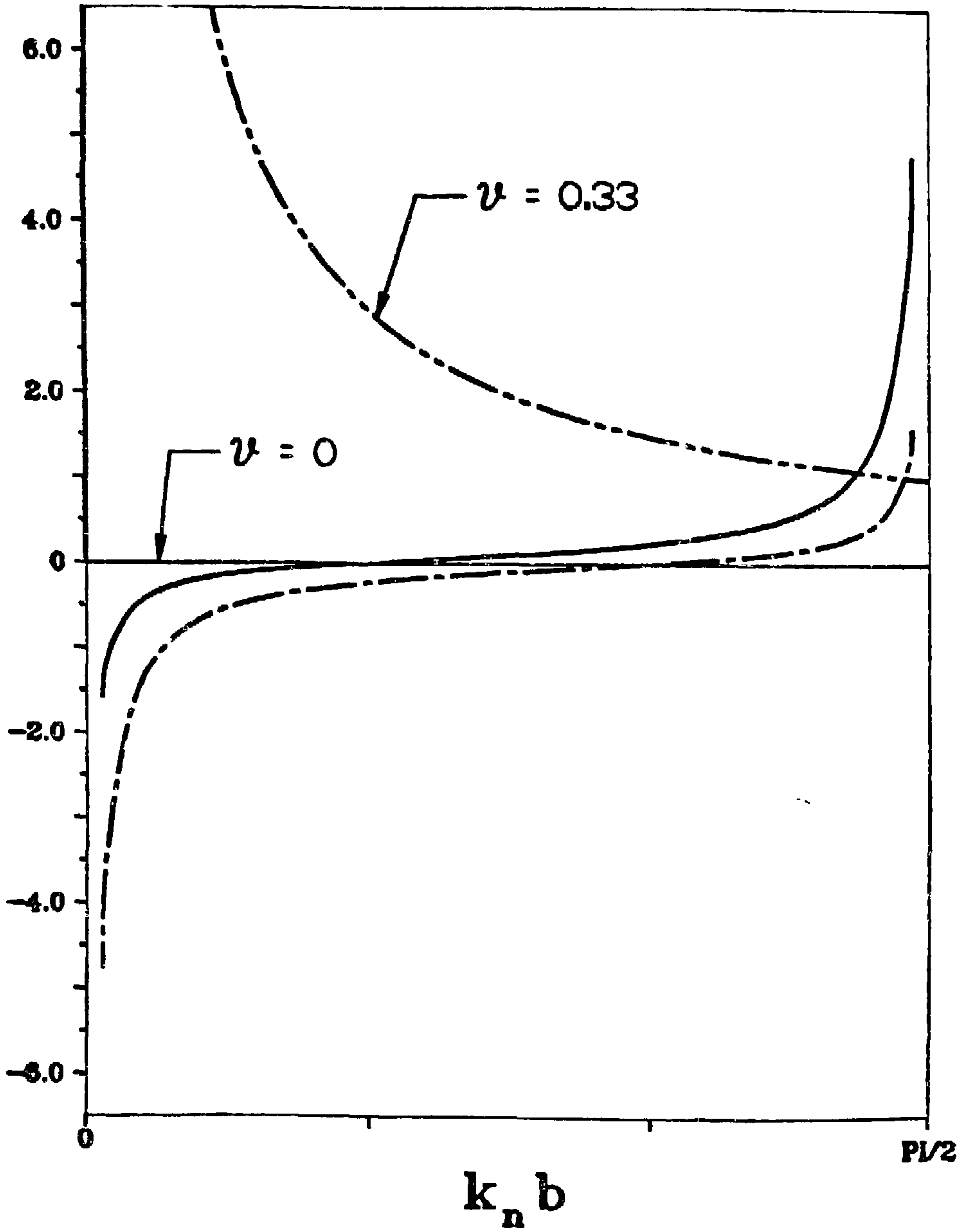
Since our point here is to simplify, we next replace the linear potential by a delta-function on the surfaces of an array of cubes. The strength of the delta-function is chosen to match the integrated strength of the linear potential across a cell. The strength is infinite on the outer surface of the cubical nucleus. The choice of cubical cells is of course made to produce a separation of variables in the Schroedinger-like wave equation. It is now a simple, one-dimensional problem in quantum mechanics to find the quark eigenmodes, by matching wavefunctions at the cell boundaries. We have checked that fluctuation of the potential strength over the face of a cube only lowers the resulting eigenenergies. Further, although our cube size ($2b = 1.8$ Fermi on a side) is fixed, it is clear that the eigenenergies will rise, due to increasing localization energy if we try to reduce the separation between them. This also occurs if we increase the separation, as the effective barrier strength increases; the linear potential must be integrated over a longer distance.

$$\frac{4\left[\cos^2\left(\frac{n\pi}{2N}\right) - \cos^2 k_n b\right]}{\sin 2k_n b} = \frac{v}{k_n}$$

[Eigenvalue equation for cubical ($A = N^3$) nuclei]

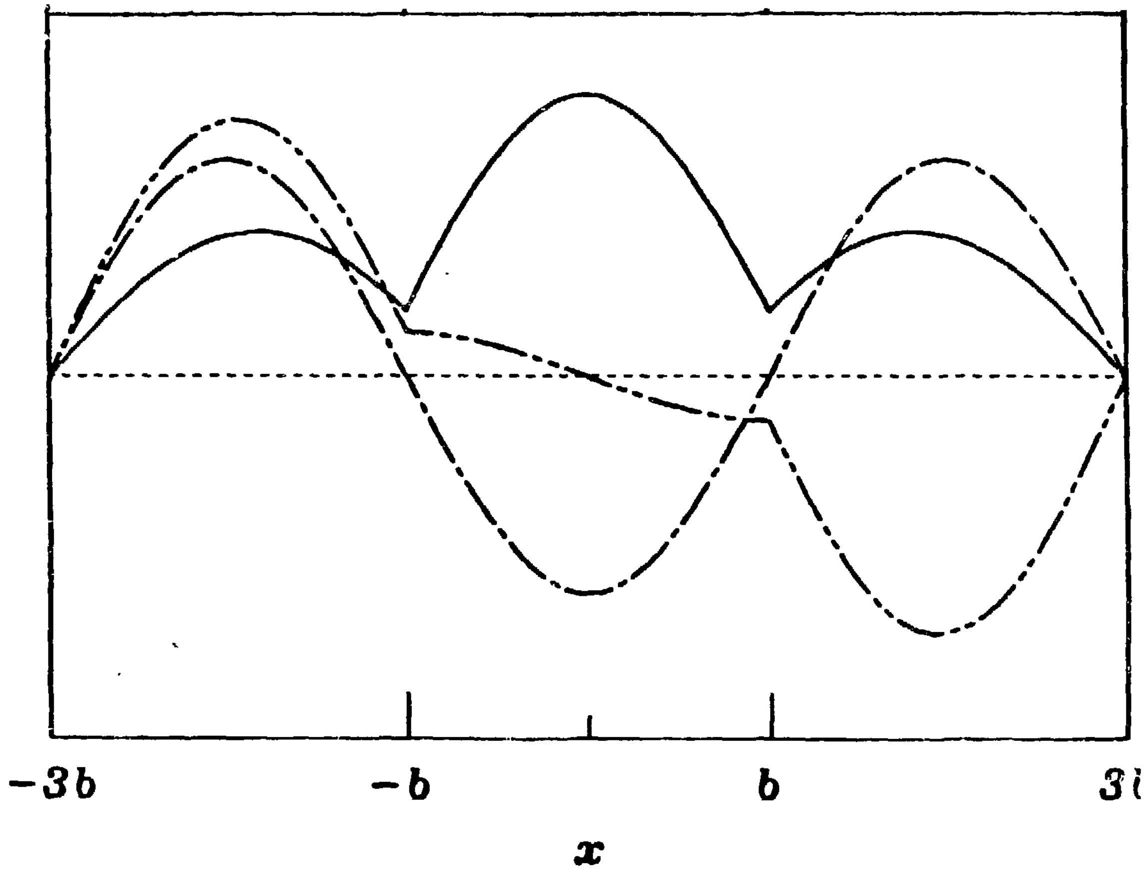
We find that[1], for realistic values of the potential strength, the wavenumbers of the eigenmodes are not enormously different from that for a single, isolated cube (nucleon). The first N modes for an $N \times N \times N$ cube cluster near, and of course

Fig. 3 Graphical solution of eigenvalue equation.



below, the value for a single cube. The absolute value of the wavefunction at the location of the delta function potential is about 10% of the maximum value. That is, the probability of finding a quark at an interstitial location, as far away as possible from the center of a cube (nucleon), is about 1% of the probability of finding it at the center. We have done little violence to the conventional view that quarks reside inside nucleons (beyond the horrible, cubical approximation itself). The next set of solutions occurs at close to twice the (momentum, and so for these completely relativistic quarks) energy of a quark in an individual nucleon. This large energy difference clearly suppresses the contributions of the higher Fock space states. Thus our first result is that valence quarks dominate the wave function.

Fig. 4 Wave functions for 3^3 nucleus.



To determine a binding energy for our "nucleus", we need to compare the energy of 3A filled states to the mass of A cubic nucleons. The mass of even a cubical nucleon is somewhat less than three times the energy of a quark wave restricted to a single cube, due to the color-magnetic spin-splitting interaction between pairs of quarks, which raises the delta and lowers the nucleon. We applied a crude correction to account for the difference between the empirical value in spherical nucleons and our cubes. The result is a set of average binding energies per nucleon between 40 and 90 MeV (depending on the potential strength), and which show evidence of saturation as A increases. These are not expected to be realistic values, but they are in the right ballpark. Since the systematics are as we had expected, we have been encouraged to attempt a more realistic case.

Table I

Binding Energy per Cubical Nucleon for Cubical Nuclei of various Atomic Weights, A.

v \ A	8	27	64	125	216	343
1.0	36	76	96	108	116	122
k_{min}	279	258	250	246	244	242
E_{min}	483	447	432	426	422	420
1.25	16	50	67	78	85	89
k	287	269	261	258	256	255
E	497	465	453	447	444	442
1.5	4	31	46	55	61	65
k	293	277	270	267	266	265
E	508	480	468	463	460	458
1.75	-11	16	29	37	43	46
k	298	283	277	275	273	272
E	516	491	480	476	473	471
2.0	-21	4	16	23	28	31
k	302	288	283	280	279	278
E	523	499	490	486	483	482

k_{max} = 333 MeV/c, E_{max} = 576 MeV

V. THE EMC EFFECT

Before turning to the more realistic problem, we briefly apply the results above to explain the EMC effect. This is the discovery by the European Muon Collaboration[2], since confirmed by electron scattering data from SLAC[5], that the scaling structure function of a nucleus, measured in deep inelastic muon scattering, is not just A times that of an average (isoscalar) nucleon. This startling observation shows that nuclear binding effects are apparent at even very high energies, where they had been naively expected to be negligible.

Many proposals have been put forth to explain the observation of a (relative to the nucleon) excess of structure function strength at low quark fractional momentum, including expanding nucleons, six-quark bags, and excesses of pions. None of these has been conclusively confirmed, and indeed the last runs into some trouble with polarization transfer measurements in proton scattering at much lower energies.[6] All we really have to say here is: Me too!

Geoffrey West has developed a formalism which shows that these structure functions may be determined from a three dimensional integral over the non-relativistic constituent wavefunction in any system. Thus the EMC effect can be seen to correspond to an increase in nuclei, over the amount found in individual (isolated) nucleons, of long wavelength, low momentum components of the quark wavefunction. It is clear from this why our picture produces the EMC effect, at least qualitatively. Even in the cubical nucleus, the boundary condition between adjacent cubes allows the quark wavefunction to flatten, relative to that in a nucleon, increasing the amplitude of low momentum Fourier components. In addition, the coherence of the quark waves over a space of many nucleon diameters also affects the strength of the Fourier components.

We have seen these effects in both the Fourier transforms of the quark wavefunctions, and in the West integral over them. In both cases, the EMC effect shows up as a low momemtum (or momentum fraction) enhancement, followed by a suppresion at higher values relative to a nucleon. Finally, at large momentum fraction (x>1 in nucleon terms), we have seen again an excess of strength, that in conventional models would be ascribed to Fermi momentum effects. In performing these calculations, we have averaged over orientations of the cube in order to restore rotational symmetry, and so as to smooth out Bragg reflection-like effects. We have not attempted to compare so crude a model to actual data.

$$f_{q/A}(x) \cong (k_0 - k_3) \int \frac{d(k_0+k_3)\, d^2k_\perp}{(2\pi)^4} \left|\psi_q(\vec{k})\right|^2 2\pi\, \delta\left((k-p_A)^2 - \omega_0^2\right)$$

[West integral]

Fig. 5 Comparison of quark wavefunctions in nucleon (—) and 3^3 cubical nucleus (---).

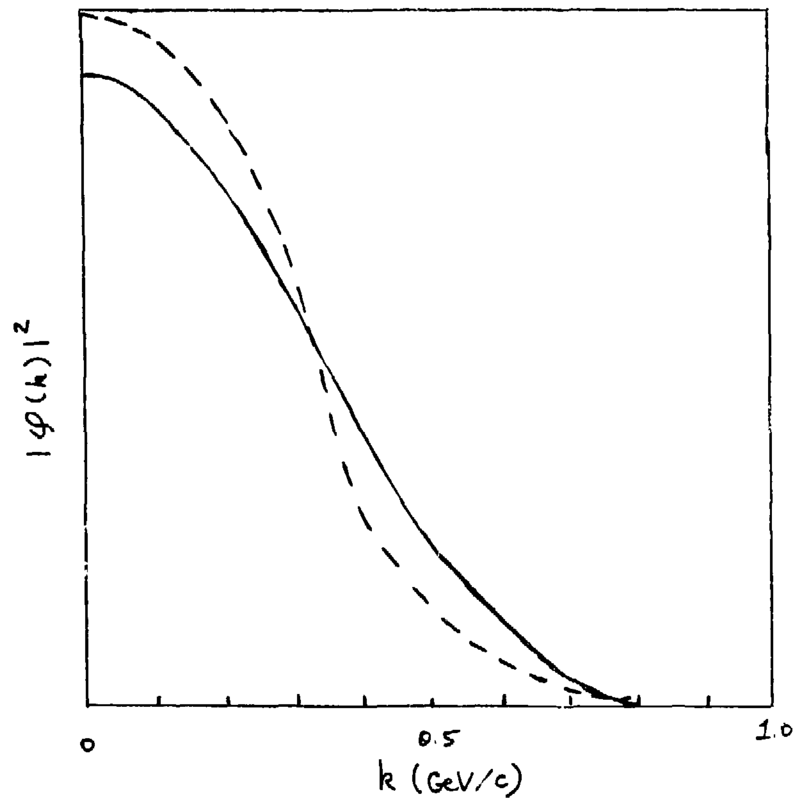
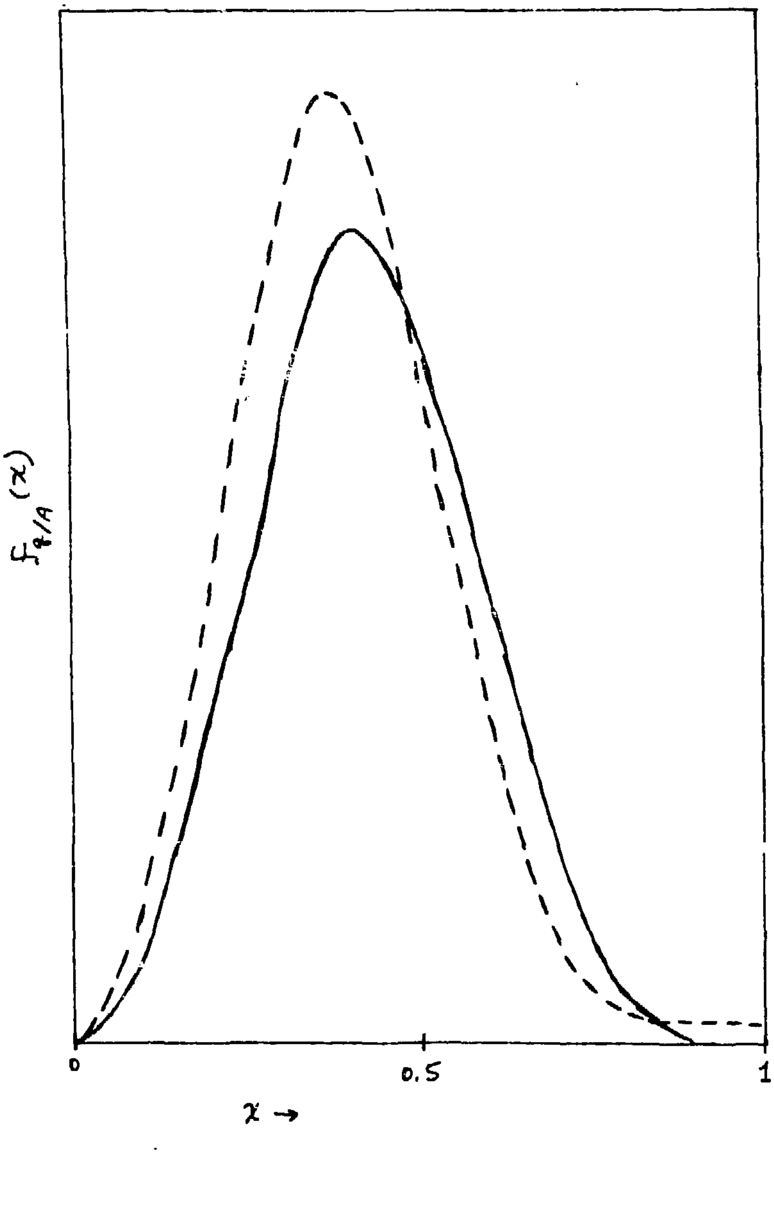


Fig. 6 Probability f of finding a quark at momentum fraction x in a nucleon (—) or 3^3 cubical nucleus (---)



VI. SMALL QUARKLEI: A=2,3,4

I would like to note, just in passing, that the linear potential fitted to heavy quark systems crosses zero at just under 0.6 Fermis from the origin. With the Feynman-Gell-Mann reduction technique, this produces a squared potential (for massless quarks) which is very flat from the origin, to about 1 Fermi out. This potential in the Schroedinger-like equation bears a strong resemblance to the structure envisaged in bag models of confinement. Thus, despite the difficulty of justifying a potential approximation for relativistic quarks, it is clear that our approach will do very well, as does the MIT bag model[7], in reproducing the hadronic spectrum.

To calculate the splitting between deltas and nucleons requires, that in addition to the electric interaction given by the potential, the spin-spin color-magnetic correlation energy between pairs of quarks must be included. Using standard SU(6) spin and flavor wavefunctions, and our own spatial wavefunctions, we can reproduce the experimental value of the delta-nucleon splitting if the value of the dimensionless strong coupling constant is about 1. For comparison, the MIT bag calculation required this value to be about 2.2, and a value of about 0.75 has been suggested by T. Barnes[8] on the basis of short distance corrections to the wavefunction due to the strength of the (otherwise universally ignored) color-Coulomb interaction near the origin. My point is not that any of these values is any better than another, but that they are all in the same ballpark. Thus, our model is not wildly different from others that have been found quite acceptable for the hadron spectrum.

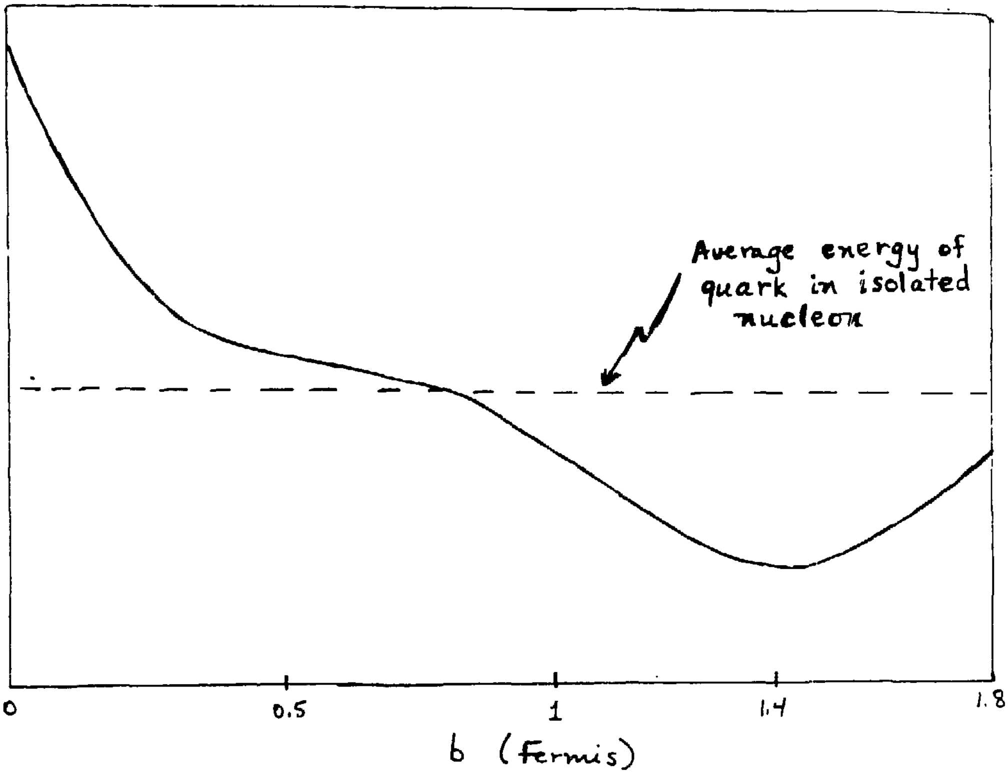
We (that is, Kevin Schmidt, our post-doc at the time) have constructed a program to calculate the full Dirac quark eigenenergies in arbitrary geometry systems of up to four potential wells (A=4). Some fortunate arithmetic errors quickly taught us that the symmetric arrays, equilateral triangle for A=3 and tetrad for A=4, are indeed the ones that provide the lowest eigenenergies for the quarks. The A=2 system is not bound, and we would certainly not expect to reproduce a dueteron with our poor description of long distance interactions. For the A=3 and 4 systems, the minima occur at separations of 1.3 and 1.4 Fermis, respectively, between the well centers. It is these energy minima which determine the nuclear structure. The binding energies are 12 and 24 MeV per quark, before including color-magnetic spin-splitting effects. These calculations do not yet include any variational adjustments to the quark wavefunctions; we have only used the symmetric sum of wavefunctions for the individual wells.

The color-magnetic spin-splitting effect overwhelms this binding energy. We concentrate on Helium-4 as its density and compactness offer a "best case" for minimizing omitted long distance (single pion) effects. It is also a convenient "closed shell" system as 12 quarks in 3 colors, 2 flavors (up and down) and 2 spin states are the maximum that can be placed in the 1S spatial wavefunction, consistent with Pauli exclusion. We find 43 MeV additional energy, on average, per quark in this case, despite a roughly factor of three decline in the matrix element of the color-magnetic operator, which arises because of the increased volume occupied by the wavefunction. (The minimum overall energy now occurs at a center-to-center distance of 1.6 Fermis between the wells in the tetrad.) The large value of the additional energy is due to a combination of the effects of the occurrence of quark pairings similar to those which appear in the delta (S=1, T=1), and of new pairings which occur in the 6-dimensional color representation. We do not know if symmetric variational adjustments to the quark wavefunctions will improve this, but adding in antisymmetric (P-wave) combinations certainly will. Note, however, that the later additions make the system look even more like one of separate nucleons than the fluctuations in the symmetric quark amplitudes did.

Thus, at present, our model is even further from describing nuclei than is a collection of non-interacting nucleons! Our point is, however, that these represent opposite extremes of zero and maximal phase correlations of the nucleon constituent quark waves. Real nuclei undoubtedly lie somehwere in between these two extremes. Introducing spatial-color correlations into our many-body wavefunctions will undoubtedly improve our results. We therefore expect that it will be possible to describe nuclei entirely in terms of quark and gluon constituents, without the need to define off-shell composite objects.

The most exciting prospect of our program is the absence of free parameters. What we need about QCD can be derived from the hadronic particle spectrum, if not (at present) ab initio. Thus, for nuclear calculations, there are no free parameters. The shape and scale of well arrays is determined by the need to minimize the quark energies. Nuclear binding energies, excitation spectra, and structures become as calculable (and independent of experimental input) as are the corresponding quantities for molecules. However, to prove that we are on the right track, it is necessary to find critical tests of features unique to our model, or to predict new phenomena based on it. The most striking new element is the occurence of color-6 representations of pairs of quarks. Unfortunately, we do not yet have any definite

Fig. 7 Quark eigenergies in tetradal nuclei as a function of the length of a side (b) of the tetrad



physical predictions based on this. Since the EMC effect has already been observed, we turn next to applying our model to new phenomena in a new nuclear sector.

VII. HYPERNUCLEI

We have calculated the eigenenergies for strange quarks of mass 130 or 170 MeV in the A=4 system, using the code referred to previously. These yield about 16 MeV more binding energy than for light quarks (it costs less energy to localize a massive quark) but this minimum occurs at a well separation of 0.9 Fermis. That is, the strange quark would prefer to have the system a little smaller than that fixed by the light quarks. Since the size of so-called Lambda-Helium-4 is more likely determined by the 11 light quarks than the one strange quark, we expand the system to its light quark size. This reduces the strange quark binding energy to about the same as for the light quarks. With just this information, we can make qualitative predictions for the systematics of hypernuclei.

The first is that, contrary to the expectation based on an entire Lambda being able to fall to the lowest (nucleon) shell model state, only the strange quark can fall into the lowest quark shell model state. The two light quarks are Pauli blocked, although they may still provide some binding energy. The separation of the strange quark from its light partners may cost further in energy. Thus, the binding energy for adding a Lambda should be about 1/3, and certainly less than 1/2, that expected from the binding energy of the lowest state nucleon in a nucleus of the same total baryon number (A). The light quarks hold the Lambda up at a higher average level in the nuclear well than that for a point particle.

Secondly, when the nucleus in which we will trade a nucleon for a Lambda is a closed shell nucleus, we predict that the hypernucleus will always show evidence of, in conventional terms, strong Lambda-Sigma mixing. This is because the strange quark which is trying to sink down to an unblocked lower energy state, leaving its light partners behind, will lose track of which light pair it "belongs" too. Since the light pair it is "near" at any time may be either T=1 or T=0, the strange-light system has roughly equal probability to appear as either hyperon. Coversely, when the A-1 nucleus is a closed shell, there is a light quark pair which is distinguishable, namely the one that is trying to act like a nucleon in the first orbital outside the closed shell. This distinguishable pair helps the Lambda to retain its identity and mixing is suppressed.

Finally, as our calculations directly show, hypernuclei are smaller than ordinary nuclei. This is opposite to the expectation in the conventional (nucleon) picture. There, the short range of the Lambda-nucleon interaction leads to the Lambda residing on the surface on the nucleus, if it is to be lightly bound, consistent with experiment. Alternatively, the Lambda may be viewed as sinking to the center of the nucleus, but there its relatively weak interaction with nucleons weakens the average nuclear potential, and allows the nucleus to expand, overall. Either way, the hypernucleus is larger. Unfortunately, the prospect is remote, to say the least, that electron scattering experiments may determine whether hypernuclei are larger or smaller than the same A nucleus. We must think of a better way.

VIII. CONCLUSION

I have tried to convince you that we know nuclei are made of quarks, and that direct QCD calculations offer hope of making nuclear physics as well defined, and as powerfully predictive, as modern quantum chemistry. We are a long way from proving this, but we are up against several thousand more man-years of effort applied to the conventional picture, including efforts by some of the "giants" of physics. More importantly, the problem is really two-fold: Both to do better, and to understand deeply why the old ways have worked so well. An improved ability to make accurate extrapolations beyond experimentally known regimes will be the hallmark of success for our approach. But for me, and I hope for you, the most stirring rallying cry for this effort has been and will continue to be: No parameters!

It is a pleasure to acknowledge many useful conversations with my colleagues in T-, P-, and MP-Divisions regarding this subject.

REFERENCES

[1] T. Goldman and G.J. Stephenson,Jr., Phys. Lett. 146B, 143 (1984).
[2] J.J. Aubert et al., Phys. Lett. 123B, 275 (1983).
[3] W. Buchmuller and S.-H.H. Tye, Phys. Rev. D24 132 (1981).
[4] R.P. Feynmman and M. Gell-Mann, Phys. Rev. 109, 193 (1958).
[5] A. Bodek et al., Phys. Rev. Lett. 51, 534 (1983).
[6] T. Carey et al., Phys. Rev. Lett. 53, 144 (1984).
[7] T. DeGrand et al., Phys. Rev. D12, 2060 (1975).
[8] T. Barnes et al., Nucl. Phys. B198, 380 (1982).

Searching for 6-quark, Hidden Color Clusters with the Pion-nucleus Double Charge Exchange Reaction

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Abstract

It is argued that the large forward cross section observed in the recent LAMPF $^{14}C(\pi^+,\pi^-)^{14}O(DA)$ experiment is indicative of the existence of 6-quark clusters in nuclear matter.

We have seen yesterday that there is tremendous interest in determining the quark aspects of the nucleus. Today I'd like to discuss one very specific means of looking for quarks--the low energy pion-nucleus (π^+,π^-) reaction. Let me state the basic result at the beginning. I believe that the relatively large forward peaked cross section seen[1] $^{14}C(\pi^+,\pi^-)^{14}O(DA)$ reaction at 50 MeV indicates that 6-quark (hidden color) clusters exist in nuclei.[2]

To understand this, let's go back to the very beginning and consider the basic aspects of double charge exchange. Long ago[3] it was recognized that the π-nucleus double charge exchange (DCE) reaction could be something special. Since two units of charge are inserted into the nucleus, and the nucleon has at most one limit of charge, two nucleons are needed to participate in the reaction. Thus, one could hope to learn about the two-nucleon wave function in nuclei. Progress in this direction has been slow due to the presence of many possible reaction mechanisms.

However, at 50 MeV there is a significant opportunity for progress. The forward cross section for π-nucleon charge exchange vanishes. This is due to a cancellation between s and p-wave terms. The startling thing is that this cancellation persists in the pion-nucleus single charge exchange (SCE) process.[4,5] Thus, multiple scattering and binding effects, which might be thought to complicate matters, do not seem to show up.

The 0° excitation function for the $^{14}C(\pi^+,\pi^0)^{14}N$ reaction is shown in Fig. 1. The solid curve represents the free π-nucleon cross section. One sees that the minimum in the π-nucleus process occurs at the same energy as for the π-nucleon reaction. Thus multiple scattering does not enter. (The current experimental upper limit is 6μb/sr[6]) but DCE proceeds

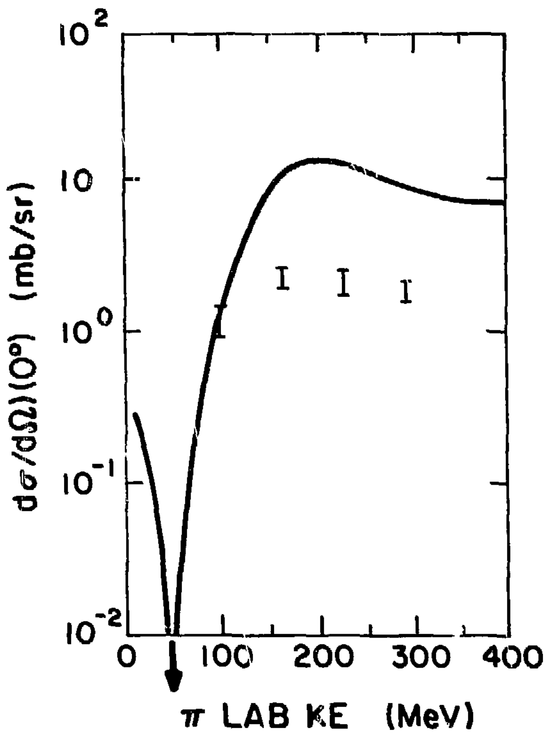


Fig. 1. Forward $^{14}C(\pi^+,\pi^0)^{14}N(A)$ cross section vs energy. Data Ref. 4.

(conventionally) by a multiple (double) scattering process. Thus if DCE results from two small angle SCE reactions, one would naturally expect it to be small at 50 MeV.

One can say even more. The angular distribution for the $^{15}N(\pi^+,\pi^0)^{15}O$ reaction at 48 MeV is shown in Fig. 2. One again sees a forward angle minimum. As indicated by the solid curve, the plane wave approximation (PWA) correctly gives the shape of the cross section at forward angles. The idea that the PWA or impulse approximation is valid at low energies allows us to place limits on multiple scattering processes. For example, a forward SCE process caused by two 90° pionic scatterings (one SCE, one non-charge exchange) could naturally be expected to contribute. This does not show up. Thus any forward DCE occurring due to two 90° scatterings should be small.

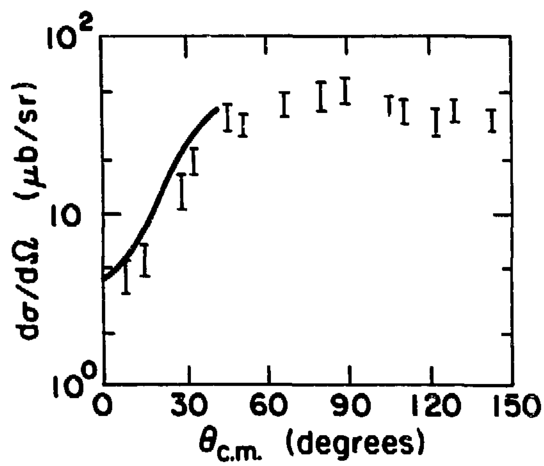


Fig. 2. Angular distribution for $^{15}N(\pi^+,\pi^0)^{15}O(A)$. Solid curve - impulse approximation. Data Ref. 5.

Although one expected DCE to be small, experiment[7] showed that this was not the case. As displayed in Fig. 3, the 50° value, $\frac{d\sigma}{d\Omega} \simeq$ 2-3 μb/sr is very large. (Typically DCE is a much rarer process than SCE. The DCE cross sections are often two or three orders of magnitude smaller than for SCE. Here the forward SCE and DCE processes occur at similar rates.

Also shown (by dashed curve) is a conventional nucleonic cross section calculation.[7] This calculation, which gives a very small DCE result, is consistent with the SCE data. Thus the DCE cross section is much larger

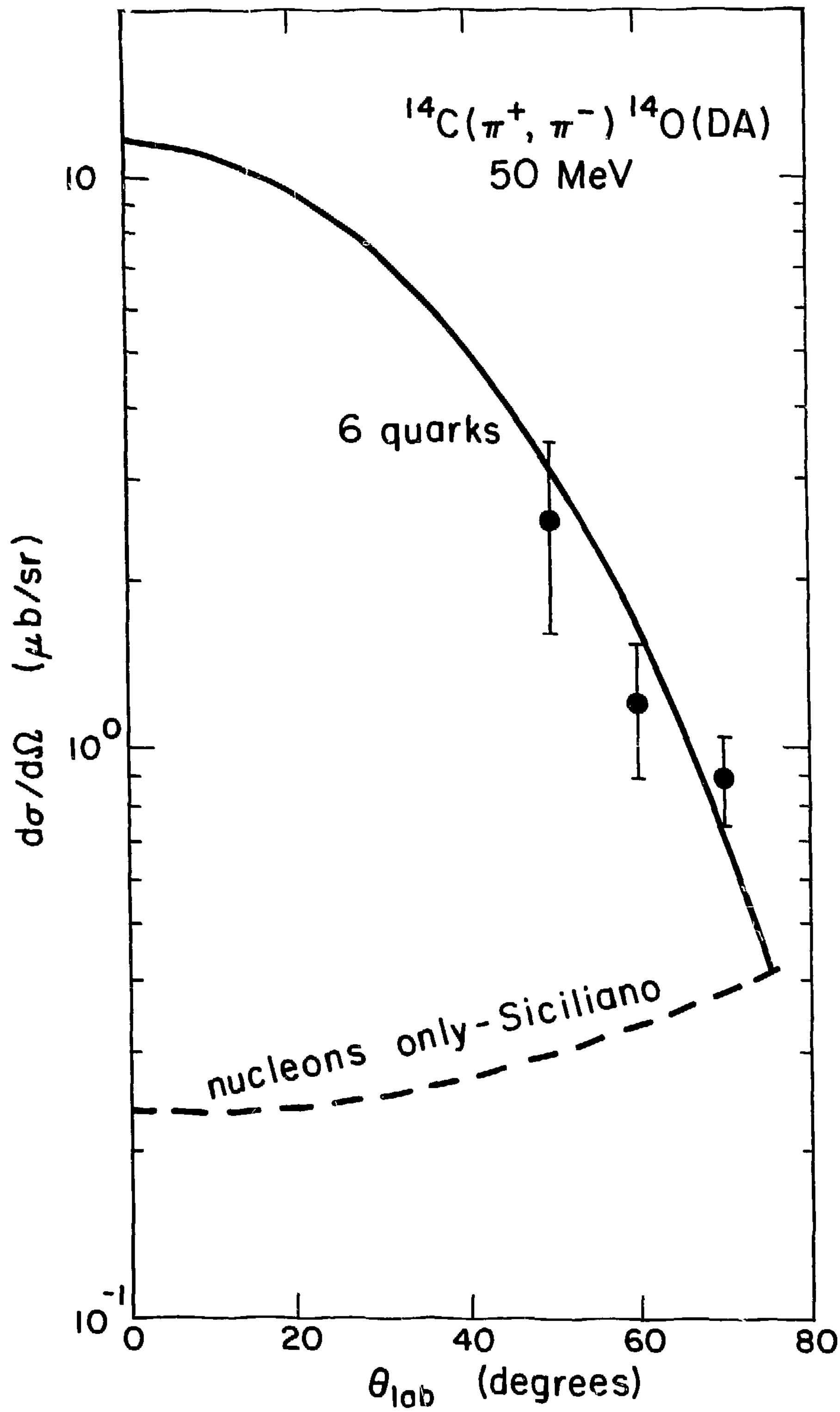


Fig. 3. $^{14}C(\pi^+,\pi^-)^{14}O(DA)$. Data from Ref. 7.

than expected. A different computation of the conventional mechanism made by Karapiperis and Kobayashi[8] gives a large double charge exchange cross section. However, these authors present no results for SCE, so I cannot discuss that work at this time.

The solid curve of Fig. 3 is in contrast with the expectations of conventional theory. It is the result of a computation in which the (π^+,π^-) process arises from pionic interactions with quarks confined in a six-quark bag.[9] Shown also is the experimental upper limit for SCE. These six-quark effects, to be discussed below, give a cross section about 0.3 times that of DCE. Thus the SCE cross section of the six-quark mechanism is safely under the experimental upper limit. The contrast between the solid and dashed curves presented a challenge to experimentalists that was quickly taken up by workers at LAMPF!

The next step is to describe the computation that provides the solid curve of Fig. 3. To see how to proceed consider the wave functions of the two valence neutrons of ^{14}C. Most of the time, this system is well described as a separated pair of nucleons. Such aspects are responsible for the familiar nuclear physics that is dominated by nucleonic effects. However, sometimes the conventional long-ranged nucleonic amplitudes are suppressed. (Here the forward SCE amplitude vanishes and, multiple scattering seems to be absent.) In such cases short ranged (separations less than about 1 fm) contributions are needed. These aspects are efficiently described by quark degrees of freedom. To be specific, in these early investigations we describe the small-distance, baryon-baryon wave functions as six quarks confined in a single spherical bag. In this simple picture, there are two varieties of nuclear matter--nucleons and six-quark bags.

To proceed further one needs to know when to use two nucleons and when to use a six-quark bag. Let's introduce the idea of a matching radius, r_0. When the two nucleon separation (r) is greater than r_0 use two nucleons. For $r < r_0$ use the six-quark bag. Thus r_0 is the parameter that determines, for us, the six-quark content of the nucleus. When r_0 is increased, these new aspects are augmented. A closely related number is P_{6q}. This gives the probability that the two nucleons contain a six-quark bag component.

Since the value of r_0 is central, I must discuss what values it can have. Although I cannot calculate this quantity, reasonable upper and lower limits can be obtained. If $r_0 > 1.2$ fm it becomes too difficult to reproduce the very nice meson exchange effects that adequately explain the long and medium range nucleon-nucleon interaction. On the other hand, it turns out that values of r_0 less than about 0.7 fm lead to very small effects of six-quark clusters. (For bound states P_{6q} is proportional to r_0^3. Matrix elements for low momentum transfer processes, such as that considered here, vary slowly with r_0. Thus small values of r_0 suppress six-quark effects.) The net result is 0.7 fm $< r_0 <$ 1.2 fm. In this talk I use values of r_0 in the middle of this range, $r_0 = 1$ fm. This seems to work well.[10]

The value of r_0 of 1 fm is close to the radius of the nucleon. This allows a geometrical interpretation of our procedure. If two nucleons interpenetrate such that the edge of one coincides with the center of the other, use a six-quark bag. For $r = r_0$, the ratio of overlap volume to the total volume is about 30%. Thus quarks in one nucleon often meet quarks of the other.

Now turn to the 6-quark mechanism for (π^+,π^-). This is shown in Fig. 4a.

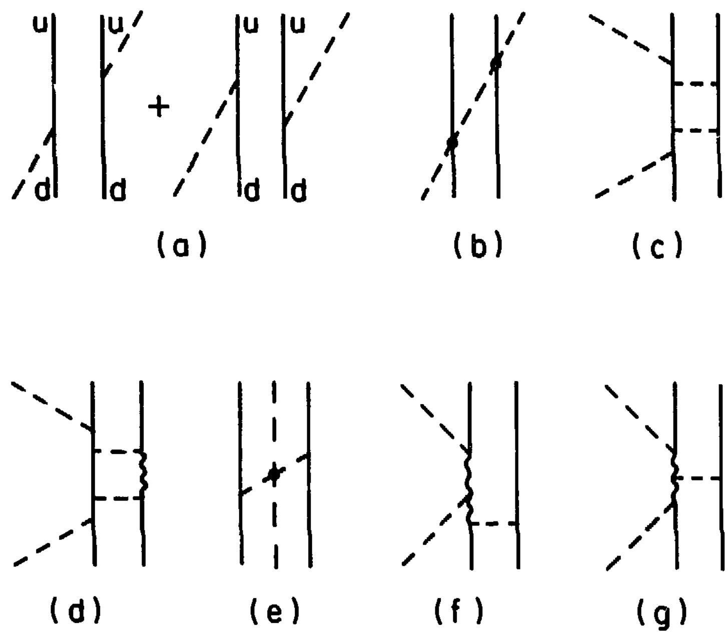


Fig. 4. Mechanisms for SCE and DCE. Dashed line pion; solid line nucleon; squiggly line delta.

A π^+ is absorbed by an up (u) quark and emitted by a down (d) quark. The center of the six-quark bag is taken to be $\vec{R}$. The π-quark interaction is taken from chiral bag models. (Simply choose the π-q vertex to reproduce the π-nucleon coupling constant, $g_{\pi NN}$.) The formula for the matrix element is given below

$$\mathcal{M}_{DCE}(\vec{k}',\vec{k}) = C \int d^3R \; e^{i(\vec{k}-\vec{k}')\cdot\vec{R}} \; P_{6q}(R)$$

$$\times \sum_n < 6q,\; S=0,T=1,T_z=1|g_{\pi NN} \sum_{a=1}^{6} \vec{\sigma}_a\vec{k}' \;\; \tau_{+(a)}|n>$$

$$<n|g_{\pi NN} \sum_{a=1}^{6} \vec{\sigma}_a\cdot\vec{k} \;\tau_{+(a)}|6q,\; S=0,T=1,Tz=-1> \qquad (1)$$

$$\times \; 2E_n/(E_\pi^2 - E_n^2)$$

where $\vec{k},\vec{k}'$ are the initial and final π momenta, $|6q,T=0,T=1,T_z\rangle$ are the initial and final 6-quark bag states, $|n\rangle$ is the intermediate 6-quark state of energy E_n. The π-quark interaction is an axial vector operator $\sum_{a=1}^{6} \vec{\sigma}_a\cdot\vec{k}\,\tau_a$ as derived from chiral bag models. C is a well-defined uninteresting constant.

The crucial elements in the calculation are: the six-quark probability P_{6q}, the initial, final, and intermediate six-quark wave functions and energies, and the matrix elements of the π-quark interaction. These are discussed in turn.

1. Six-quark probability, P_{6q}. Conservation of probability may be employed to constrain this number. Suppose $\psi(R,r)$ is the wave function of two-valence neutrons, ($\vec{R} = \frac{\vec{r}_1 + \vec{r}_2}{2}$ and $\vec{r} = \vec{r}_1 - \vec{r}_2$. However for $r < r_0$ a six-quark bag is used instead of two nucleons. Thus probability is removed from the conventional 2-nucleon wave function. This is replaced by an equal amount of probability in the six-quark sector. Hence

$$P_{6q}(R) \equiv \int d^3r\ \theta(r_0 - r)\ \psi^2(R,r)\ . \qquad (2)$$

Here $r_0 = 1$ fm and $\psi^2(R,r)$ is derived from the product of two p-shell oscillator wave functions with oscillator parameters $b = 1.6$ fm. The forward DCE amplitude is proportional to P_{6q}, with

$$P_{6q} = \int d^3R\ P_{6q}(R)$$

and is about 6% here. Note also that $P_{6q} \propto r_0^3/b^3$.

2. Six-quark states. All states are formed by placing six quarks in the lowest energy single-quark orbital ($\kappa = -1$). Such states have the [6] symmetry under permutations. These have an interesting content. If you decompose the wavefunctions into sums of products of baryon-baryon wave

functions, it turns out that 80% of the probability occurs for configurations in which a color baryon (3) is coupled to another colored baryon ($\bar{3}$) to form a color singlet. Such product wave functions are said to have "hidden color".[11] The initial $|i\rangle$ and final $|f\rangle$ states have spin (S) 0 and isospin (T) 1. The intermediate states $|n\rangle$ are those connected to $|i\rangle$ and $|f\rangle$ by the axial vector π-quark interaction. These have S=1 T=0 and S=1 T=2 with energies of 290 MeV and 500 MeV (above two nucleon masses) respectively.

3. The matrix elements of the $\sigma\tau$ operator are determined by employing tabulated coefficients of fractional parentage.[11] The essential reduced matrix elements are

$$\langle S=1\ T=2 || \sum_{a=1}^{6} \sigma_a \tau_a || S=0,\ T=1\rangle = 8\sqrt{2}$$

$$\langle S=1,\ T=0 || \sum_{a=1}^{6} \sigma_a \tau_a || S=0,\ T=1\rangle = -10\ .$$

The input described above leads to the solid curve of Fig. 3. However, one more effect is needed before comparison with the recent LAMPF data[1] is to be made. Multiple scattering effects are small at 50 MeV, but the effects of a π disappearing due to its absorption on a pair of nucleons should be included. This effect reduces the cross section in an angle dependent manner. Pions moving straight through the nucleus, must traverse more matter than pions scattered off to the side. this effect is included in a very simple classical calculation. The pion mean free path, λ, is given by the relation $\lambda^{-1} = \frac{2E_\pi}{k}$ ImU

where U is thè optical potential as determined by McManus et al.[13] Using values of ImU in the range allowed by elastic scattering and pionic atom data gives $\lambda \cong 7$ fm. The path length $\langle L(\theta)\rangle$ is taken by averaging the path lengths (obtained for a scattering angle θ) over the regions in the nuclear volume at which the DCE events occur. The results of all of this, along with the LAMPF data, are shown in Fig. 5. There the dot-dashed curve is a sequential optical model calculation of Leitch et al. The dashed curve is the original 6q results shown in Fig. 3, and the solid one is the same model with annihilation effects incorporated.

The six-quark bag computation gives a large forward peaked cross section which is in qualitative (dashed curve) and even quantitative (solid curve) agreement with the new data. To a large extent the original prediction was verified.

Note also that the 6-quark bag mechanism gives a very small SCE cross section. The ratio of SCE to DCE is 0.3. This results from a partial cancellation, in SCE, between terms arising from the two intermediate states with isospin 0 and 2.

Next turn to the difficult task of determining if six-quark clusters provide the only explanation. I can only give a plausibility argument to rule out conventional mechanisms. Indeed there are a host of possible terms: double scattering; tru pion absorption; local field corrections, π-π scattering; Δ's in nuclei and Δ-nucleus charge exchange. The basic idea is as follows: assume that your favorite mechanism gives a forward

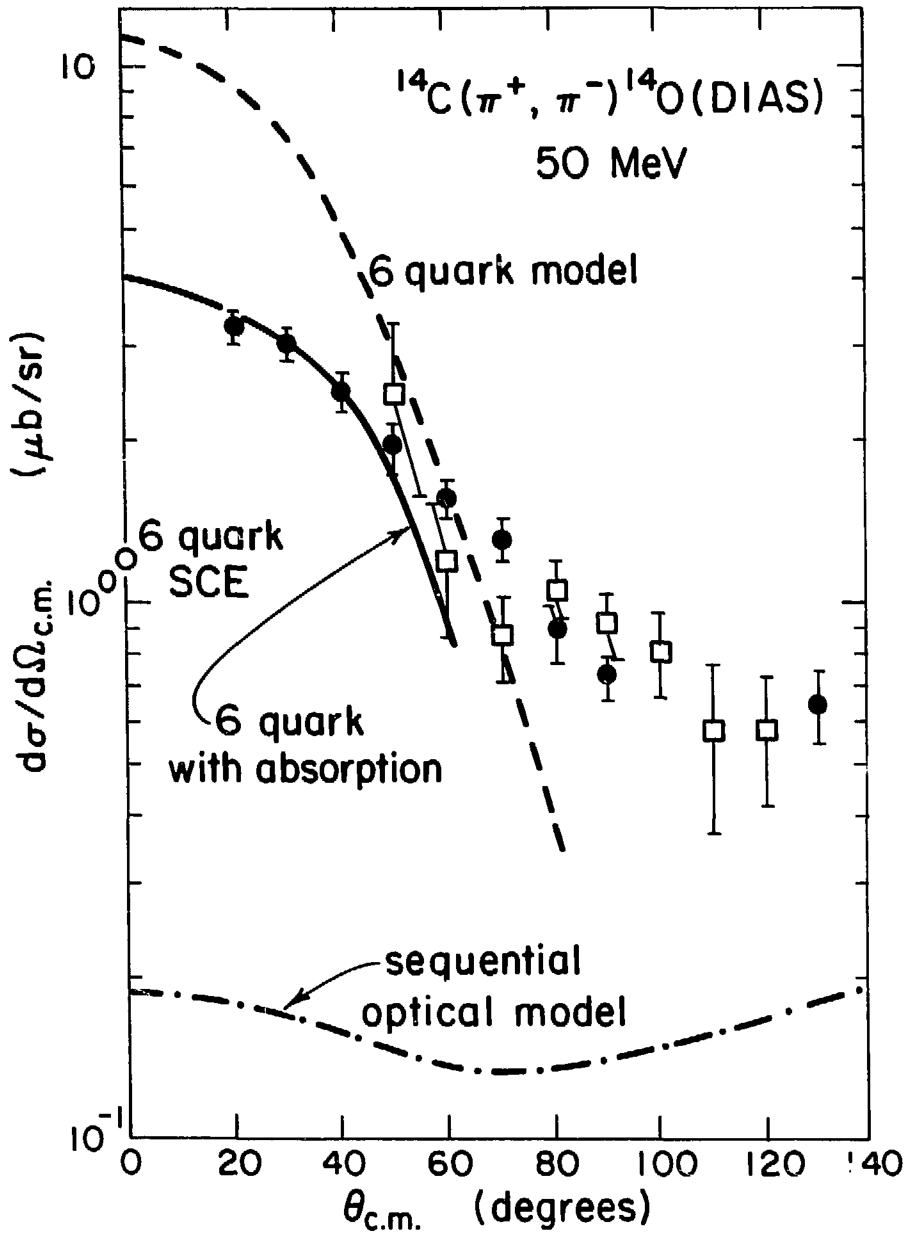


Fig. 5. $^{14}C(\pi^+,\pi^-)^{14}O(DA)$ at 50 MeV.

double charge exchange cross section of ~4μb/sr. Then compute the ratio of SCE to DCE forward cross sections. (One may have better luck in dealing with ratios than absolute values.) It turns out that

$$\frac{d\sigma_{SCE}}{d\sigma_{DCE}} \geq 2$$

in all cases I've looked at. This gives a forward SCE cross section of 8μb/sr which is above the experimental upper limit.

Let's look again at double scattering. This is shown in Figs. 4b and c. The DCE process (Fig. 4b) has an analogous SCE term with one non-charge exchange (isoscalar) interaction. The isoscalar interaction has no S-P cancellation. In the rough calculations I've done the SCE to DCE amplitude ratio is dominated by a very large factor of approximately 2A. The two comes because either of 2 neutrons are available for charge exchange. The factor of A arises since any of A nucleons can participate in the non-charge-exchange interaction. With this result, a large DCE double scattering term implies that the corresponding SCE term is gigantic. This contradicts the data.

There is one caveat in all of this. SCE allows an interference between 1 and 2 step terms. If this is responsible for the small value of the forward SCE, then the existence of the zero should be very A-dependent. It's not.

I discuss one more term here. This is the π-π scattering term of Fig. 4 e. Since only analog states enter, the isospin matrix elements are the only relevant quantity in the SCE to DCE comparison. For DCE two charge raising operators which give a factor of $(\sqrt{2})^2 = 2$ appear. In SCE one gets $-\sqrt{2} - \sqrt{2}$ since there are two possible terms. Hence the SCE to DCE cross section ratio is $(\sqrt{2})^2$. Thus this process is ruled out, if 6μb/sr is the upper limit of the SCE forward cross section.

There are other terms to consider. Some are discussed in Ref. 9. The same kind of argument gives large SCE cross sections for processes I've considered. The reason is that there are many ways for SCE to proceed.

I've given rough arguments here, but one may also use experimental data to rule out competing possibilities. For example, studies of the A dependence at the forward angle minimum seen in SCE could yield information about possible interference effects. (The A dependence of 50 MeV DCE is also interesting.) One may use existing SCE inelastic data to get limits on multiple scattering contributions to DCE. (This is because 2 inelastic SCE events yield a relevant DCE contribution.) Similarly, studies of $\pi^+ nn \rightarrow np$ in nuclei should place limits on DCE via $\pi^+ nn \rightarrow np$ followed by $np \rightarrow \pi^- nn$. There are a host of other possibilities.

On the theoretical side better calculations of all reaction mechanisms are needed!

Clearly much more work must be done before all questions are settled. Nevertheless I think the following statements provide an accurate summary at the present time (October, 1984). For 50 MeV π-^{14}C interactions, only the 6-quark bag mechanism gives a large forward DCE cross section and a smaller one for SCE. The results of our DCE calculation agree with the existing data. I believe that the observation of the large forward DCE cross section indicates that the recent LAMPF DCE experiment[1] has seen 6-quark clusters in nuclei.

References

1. M. J. Leitch et al., LASL Preprint Aug. 29, 1984, "The double analog transition $^{14}C(\pi^+,\pi^-)^{14}O$ at 50 MeV", submitted to Phys. Rev. Lett.

2. For the charge exchange reactions considered here, the final state is in the isospin multiplet of the target ground state. For DCE, this state is denoted by DA. For SCE the final state is denoted by A or IAS.

3. e.g. R. G. Parsons, J. S. Trefil and S. D. Drell, Phys. Rev 138, B487 (1965).

4. F. Irom et al., Phys. Rev. C28, 2565 (1983).

5. M. D. Cooper et al., Phys. Rev. Lett. 52, 1100 (1984).

6. H. Baer, private communication.

7. I. Navon et al., Phys. Rev. Lett 52, 105 (1984).

8. T. Karapiperis and M. Kobayashi, SIN preprint 84-14 "Multiple scattering approach to pion double charge exchange at 50 MeV."

9. G. A. Miller, U. Wa. preprint DOE/ER/40048-12-N4, "Searching for six-quark cluster components of nuclear wave funcitons with the pion-nucleus double charge exchange reaction", submitted to Phys. Rev. Lett.

10. G. A. Miller "Building the nucelus from quarks: the cloudy bag model and the quark description the nuclear wave function" in Quarks and Nuclei, Vol. 1, W. Weise ed. to be published by World Scientific.

11. M. Harvey, Nucl. Phys. A352, 376 (1981).

12. P.W. Mulders and A. W. Thomas, J. Phys. G Nucl. Phys. 9, 1159 (1983).

13. K. Stricker, J.A. Carr and H. Mc Manus, Phys. Rev C 22, 2043 (1980).

ENERGETIC PION CHANNEL AND SPECTROMETER (EPICS) WORKING GROUP
William Cottingame, Chairman

Attendees: P. Alons, University of Colorado
L. C. Bland, Indiana University
R. L. Boudrie, Los Alamos National Laboratory
K. Boyer, Los Alamos National Laboratory
A. Browman, Los Alamos National Laboratory
G. Burleson, New Mexico State University
W. Cottingame, Los Alamos National Laboratory
K. S. Dhuga, New Mexico State University
J. Faucett, New Mexico State University
S. Mordechai, University of Texas
C. F. Moore, Universtiy of Texas
C. L. Morris, Los Alamos National Laboratory
B. Nefkens, University of California at Los Angeles
J. Peterson, University of Colorado
S. Seestrom-Morris, University of Minnesota
H. Ziock, University of California at Los Angeles
J. Zumbro, University of Pennsylvania

Dick Boudrie informed the group of the work which was planned for the shutdown, which includes:

1) Rebuild FJ3 and FJ4,
2) Install energy degrader
3) Improve radiation shielding (needed for large spectrometer angles)
4) Replace water lines
5) Checkout FM's
6) Perform floating wire measurements for BM05 and BM06
7) Checkout BM05 and BM06 for ohmic integrity
8) Install sampling scintillator for in beam monitor
9) Path length, scattering angle and energy studies
10) Counting house upgrade
11) S1 in/out transport mechanism to be designed
12) Replace the 730 VAX with a 750
13) Larger computer disk for replay

The attendees encourage the replacement of the VAX, CPU, operating system and software to improve the response of the computer. Installation of ETHERNET between the counting house and the DAC.

The next chairman of the EPICS Working Group wil be John Zumbro.

COMPUTER FACILITIES WORKING GROUP
Jim Amann, Chairman

Jim Amann was reelected as chairman for the coming year. Earl Hoffman reported on MP-1 support for data acquisition and analysis in the coming year(s). FY85-87 are expected to be years of continued development, FY88-90 to be years of exploitation in preparation for LAMPF II. A budget of $400K is expected in FY-85. Probably will be spent on several (2?) VAX-750's. Development will continue on the buffer processor system, which received very high priority in the long-range planning committee study. Current data acquisition support is 4.5 FTE's dropping to 2.0 by FY-90. Support will likely decrease by 25% in FY-85 compared to FY-84 and drop another 0.5 FTE in FY-86. Loss of manpower means users need to become more self-sufficient. Loss of support will come in consulting and problem solving.

An amount of $400K was requested for enhancements to the DAC in FY-85. It currently appears as if we may not be able to get a new VAX-8600 (=4 times VAX-780)for that amount in FY-85. May be able to get some increase in disk space but not much else this year. More 6250 BPI tapes and expensive laser printer are likely not possible. We are running out of resources in the DAC and things will likely get worse in the coming year. Will likely see more competition for 6250 BPI drives. Personnel support will remain about the same but less time will be spent in consulting and more time in problem solving.

Computer maintenance will have stable funding and manpower in FY-85. Comaint received very few after hours call-ins. Materials costs dropped substantially probably due to replacement of old hardware. Time to repair was in the range of one hour.

Martha Hoehn reported that modifications to connect the 6250 BPI tape drives to the HSC and G0 floating hardware for MPBG1 are already on order. Additional memory (4 MB each) is on order for the V4.0 VAXes which should help alleviate poor system response. One additional RA-81 disk was ordered but was received damaged. It is currently under test. A small HP laser printer is under development and test at the DAC. EUNICE (a UNIX emulator) is installed on MPFG0. In order to usably upgrade MPFG0 to V4.0 it would be necessary to buy new memory controller and additional memory. May retired MPFG0 when we get VAX-8600. Probably will run V3.6 on MPFG0 for some time yet. Tony Gonzales will manage the LAMPF Ethernet system. First link will go to EPICS. Waiting on cable to be pulled and DEUNA hardware. Access to off-site computers via CCF TELENET connection has been successful.

Problems seen are that we are running out of CPU cycles with present hardware and we probably won't get much more out of tuning system. Scratch disk space is in short supply and more will be needed to effectively utilize a larger/faster machine. The MICOM terminal network is near capacity. No plan as of yet for expansion implying that we may not be able to hook up new terminals. The 11/70's at the DAC are still in use and will be left in place for replay. User input is requested for planning purposes.

Tom Kozlowski reported on the data acquistion section plans. Development will be continued on the buffer processor system. The RSX-11M version of Q will be upgraded to V4.1 and Fortran-77. An effort will be made to bring up Q on a Q-bus machine (micro-PDP). Will try to move VMS Q entirely to native mode - eliminating compatibility mode which is not available on Micro-VAX. Would like input from user as to pro's/con's of upgrading to VAX-750's for data acquisition computers.

Mike Oothoudt reported on Buffer Processor project. Goal is to get VAX-780 event analysis speed for $60K. Use 11/73's connect via Ethernet to host PDP (VAX later). Phase I in 13-52 weeks depending on fraction of time spent on project. Conversion to use VAX host an additional 4-8 weeks. Phase II is another year. Intended primarily for data replay but not restricted to it - may also be useful in Monte-Carlo problems.

Jim Amann reported on use of VAX-730 for data acquisiton at EPICS in place of 11/45. Speed of analysis is roughly same as 11/45. Reliability is at least as good. Some problems were experienced using DATUM/Kennedy tapes since DEC does not support TU-10's on VAX. Sluggish terminal response is worst user complaint. Problem caused by slowness if VMS in spawning tasks. A VAX-750 is probably a better choice for upgrading systems. EPICS will replace 730 with a 750 (swap with C-Division) and get new tape controllers which emulate DEC TS-11. Will try a few software changes to help terminal response and get a larger disk (456 MB) to use for spooling tapes for replay. HRS tried new 6250 BPI tape drives and controllers. Now working quite well after some startup problems.

There followed open discussion of previous topics. Regarding the reduction in DAC support it implies that MP-1 will not be able to write MBD code for users. Biggest consulting load (75%) is now with new users and new experiments and reduction may cause them some trouble.

Both J. Amann and R. Williams expressed and interest in testing CAMAC ACC (with 11/73) for frontend processing. Other labs working on similar problems but with not much collaboration.

Big problems are expected in the DAC because of limited computing capacity. Some discussion about ways to allocate time and priority. No concensus reached. Agreed that the working group should initiate a meeting to discuss possible allocation policies.

With regard to VAX data acquisition, EPICS users on the whole liked the VAX despite the poor terminal response. A VAX 750 should be a clear winner. It is much easier to change from RSX to VMS for data acquistion than to go from RSX-11D to RSX-11M. Other than for HRS and EPICS there was no big enthusiasm for going to VAXes in counting houses (at least among those present at the time). However, 6250 BPI tape drives seem to be a natural progression since they do not force user into something new but do give new capability to those who require it.

HIGH-ENERGY PION (P^3) CHANNEL WORKING GROUP
Jon Engelage, Chairman

<u>Attendees</u>: E. Bush, Los Alamos National Laboratory
B. Briscoe, George Washington University
D. Cochran, Los Alamos National Laboratory
J. Engelage, UCLA
D. Fitzgerald, Los Alamos National Laboratory
D. Geesaman, Argonne National Lab
S. Hoibraten, Massachusetts Institute of Technology
B. Nefkens, UCLA
J-C. Peng, Los Alamos National Laboratory
G. Rebka, University of Wyoming
J. Simmons, Los Alamos National Laboratory
D. Werbeck, Los Alamos National Laboratory

The meeting was brought to order by Jon Engelage, Chairman. The first order of business was the election of the new chairman. W.J. Briscoe was nominated and elected. Nominations were then requested for membership to the TAP and PAC. These recommendations were passed on to the User Liaison Office.

Opinions were sought concerning the possibility of installing a VAX 11/750 in one or both of the P^3 counting houses. While the advantages of being able to support larger data acquisition programs and being able to replay in in the counting house were brought up, several members of the committee feared that the speed of data acquisition may be reduced. The committee certainly would not want the data acquisition computer to be the limiting factor in handling data. Several members of the committee expressed the desire to place faster-buffered electronics on a higher level of priority than it currently is. Also most of the committee found fault with the constant removal of components of the P^3 computers for spare parts.

The chair read the committee a statement which emanated from the Computer Facilities Subcommittee. This statement suggested that the software consultation support of Q would be reduced. The following resolution was passed unanimously.

We are concerned about the suggested decrease in support of the Q acquisition package. We want sufficient consultation support availabile to the experimenters so that they may carry out their work of scientific research.

Jon Engelage then reported on what has happened in P^3 during the past years.

The ports requested last year to connect the counting houses to the DAC are installed. A motion was past unanimously to ask MP-1 to install VT-100's at these ports. A second motion was passed that two graphic terminals be available in each counting house during data taking.

The request that the LAS spectrometer be supported by the lab met with some success. The wire chambers were rebuilt but still are a source of problems. Is LAS to be supported by the lab? Don Cochran reminded the committee that it must consider that there are several other spectrometers on-site for which laoratory maintenance is being requested. QUESTION: Does not the experimenter have some responsibility? Are the grad students being trained to be just computer jockeys without hardware experience?

The higher duty factors requested last year were delivered. The members of the P^3 committee expressed great appreciation for the higher duty factor and encourage its continuance.

The computer link to the home institutions of the users is available through the Telenet system.

Don Cochran gave a report on the proposed schedule. It is planned to go from the end of April to mid-December and will encompass 3500 hours of beam time. The hope is to wipe the slate clean of all P^3 A&B^+ experiments for which the PAC has allotted running time. The usual trade off between P^3E and P^3W will be made to minimize loss of beam time during tear down and setup of experiments. The π^o Spectrometer will be moved to P^3E sometime during the next running period. This will take about six weeks to accomplish depending on available manpower.

Ed Bush then gave a talk about experimental support. All available manpower is now concentrated on the energetic shutdown in progress. Work is being done on the H^-, P^-, low energy H^+ transport systems. The switchyard has been emptied. Soon the installation, alignment and vacuum crews will be brought into service. The magnet measurement crews are busy preparing the magnets for installation. The work is ahead of schedule. MP-8 can provide engineering and design support now for users. Construction work must be put into the queue to be dove tailed into the current high priority work for the shutdown so get your requests in now for experimental jobs.

Dick Werbeck brought us up to date on plans for the Area. Steel plate will be laid down in P^3E for the π^o Spectrometer (inside the LAS brack).

Experimenters will probably want to adjust the height of counter stands to allow for this. A new quadrupole doublet has been installed after Q16 in P^3E. Dan Fitzgerald can supply the specs for TURTLE and TRANSPORT decks. A spot of 1 cm in diameter was obtained at the 6 meter pivot point of LAS. There are no plans to reinstall the A-2 jaws unless absolutely needed by an experiment. If an experimenter wants the jaws installed, he should anticipate at least a one-year lead time. Dick also mentioned that while the major construction equipment for experiments in P^3E and W has decreased (relieving MP-8) the reuse of the large setups require heavy manpower committments from MP-7.

Dan Fitzgerald told us of several improvements in P^3. There were no problems with running 705 MeV/c pions through the channel transport. (No power supplies tripped.) 10^5 π^-'s per 1% momentum bite were obtained. An improved high energy π^+ beam is hoped for with the development of a new reliable electrostatic particle separator. MP-13 is now working on a 5 foot 400 kV separator to be ready in 1985 and a 10 foot-500 kV separator to be readied in 1986. Also under development is a sampling grid scintillator which consists of a 3 mm thick lucite paddle with 1 mm cylinders of scintillator embedded at 1 cm intervals. The first tests are promising. While the absolute calibration is only known to 10%, it is felt that 1% accuracy is likely. It is even now an excellent relative monitor handling 10^7 pps (10^8 instantaneous). The pileup at 10^6 is only 1%. Good device for measuring beam contamination.

The topic of the H^+ chopper was brought up which resulted in the following resolution. Since measurements of accurate absolute cross sections and relative π^+/π^- yields require knowledge of pion beam contaminants, this committee encourages the LAMPF administration to place as a high priority the reinstallation of the one device which is necessary to make these determinations--the H^+ chopper.

The topic of dispersed beam in P^3 was again brought up. Reply--the fact that the focal plane is at 3° to the beam makes a useful dispersed beam very unlikely in P^3.

The question of making energy and flux determination during development time was given a positive response. Users were encouraged to participate in these measurements. Point: If the chopper becomes available and if PSR is getting 12 bps, then the chopper can be left on and energy and contamination determination can be made during experiments using the sampling scintillator for the time-of-flight measurement.

A request was made for a second patch panel in P^3E near the rear of the cave. It was suggested that, since the π^0 spectrometer will require that a new patch panel be installed, the requestor talk to those performing this task.

HIGH RESOLUTION SPECTROMETER (HRS) WORKING GROUP
M. Gazzaly, Chairman

Attendes: B. Aas, UCLA
A. Bacher, Indiana University
L. Bimbot, University of Paris
T. Carey, Los Alamos National Laboratory
R. Fergerson, University of Texas
M.M. Gazzaly, University of Minnesota
C. Glashausser, Rutgers University
N. Hintz, University of Minnesota
G.W. Hoffmann, University of Texas
G. Igo, UCLA
K. Jones, Los Alamos National Laboratory
J.B. McClelland, Los Alamos National Laboratory
S. Nanda, University of Minnesota
Y. Ohashi, UCLA
G. Pauletta, University of Texas
L. Rees, Los Alamos National Laboratory
S. Seestrom-Morris, University of Minnesota
B.M. Spicer, University of Melbourne
N. Tanaka, Los Alamos National Laboratory
C.A. Whitten, UCLA

The HRS facility report was presented by K. Jones. The main points were as follows:

- The focal plane shielding will be installed during the 1984-1985 shutdown. Testing will take place during Cycle 42.
- The Faraday Cup project will be completed in the near future.
- Remote control capabilties for the Line C ISICS system will be implemented. This will enable CCR personnel to tune the beam in Line C.
- New electronics have been installed for the focal plane wire chambers.
- Problems with the change in efficiency across the focal plane wire chambers have been observed during Cycle 41. The reasons for this change is not understood at the moment and is under investigation.
- In addition to the efficiency problems, spurious structure has been observed in the spectra of all focal plane wire chambers. The origin of this structure is not known at present.
- The new high density tape drives installed recently are now performing satisfactorily. Initial problems have been resolved.
- Front end on-line data pre-processing using the 11/60 computer and Camac modules is under investigation. This process, if successful, will result in an increase in the number of the good events written on the data tapes.

- MP-10's desire to maintain the 11/60 computer mostly for on-line experiment replay has been expressed.

The working group has strongly adopted a recommendation to replace the present data acquisition computer (11/45) with a 11/750 VAX.

The 11/60 computer scheduling was discussed. The following guidelines have been agreed upon by the users:

1. Four six-hour shifts per day.
2. The on-line experiment has priority over the midnight shift only.
3. The on-line experiment is allowed to compete for a second shift subject to the same rules as other users.
4. The length of individual shifts (six hours at present) will be adjusted upon the implementation of the array processor.

The main guidelines followed in selecting an experiment from the HRS queue to run were mentioned by J. McClelland. These are:

1. The high priority experiments run first.
2. Experiments with the same priority are equal.
3. Within the constraints of beam energy spin direction and priority, the experiment which has been the longest in the HRS queue runs first.

The overlap between the different working group meetings was found undesirable. It was suggested that a schedule with less overlap would be beneficial. Such schedule could be achieved by:

1. Less number of invited talks at the meeting.
2. Some of the working groups to meet on t'e evening preceeding the first day of the user meeting.

The users recommended that the beam schedule be sent to all the users whenever possible.

The working group suggested names for the TAP and the HRS PAC which were given to the User Liaison Office.

S.J. Seestrom-Morris was nominated and unanimously elected as the new HRS Working Group Chairperson.

LOW-ENERGY PION (LEP) WORKING GROUP

M.J. Leitch, Chairperson/B. Ritchie, Chairperson Elect

Attendees:
P. Alons, University of Colorado
H. Baer, Los Alamos National Laboratory
M. Blecher, VPI and State University
R. L. Boudrie, Los Alamos National Laboratory
J. D. Bowman, Los Alamos National Laboratory
D. Cochran, Los Alamos National Laboratory
J. Comfort, Arizona State University
M. Cooper, Los Alamos National Laboratory
D. Fitzgerald, Los Alamos National Laboratory
E. Gibson, California State University, Sacramento
S. Hoibraten, Massachusetts Institute of Technology
F. Irom, Los Alamos National Laboratory
J. Knudson, Arizona State University
M. J. Leitch, Los Alamos National Laboratory
R. J. Peterson, University of Colorado
B. Preedom, University of South Carolina
R. P. Redwine, Massachusetts Institute of Technology
B. G. Ritchie, University of Maryland/Arizona State University
J. Ullman, University of Colorado
R. Werbeck, Los Alamos National Laboratory
C. S. Whisnant, University of South Carolina
K. Ziock, University of Virginia

The members of the working group present elected Barry G. Ritchie (Arizona State) chairman for the upcoming year.

The working group discussed suggestions for PAC and TAP members, and a list was given to the User Liaison Office.

Dan Fitzgerald presented a summary of problems and development for the LEP channel. A new quadrupole doublet has been installed in the channel, and the cause of the severe water leak at BM01 is being investigated. In general, the channel performed satisfactorily aside from the water leak problem. Fitzgerald then presented a summary of studies of high purity very low energy pion beams. Two methods were investigated: a degrader/separation approach and a crossed-field separator. In the degrader/separation method, the e/π ratio was improved by a factor of about 4.9 at 85 MeV/c, with the μ/π ratio essentially unaffected. However, straggling in the degrader resulted in the beam spot size doubling, and the pion flux was reduced by 60%. The method does have the advantage of simplicity of implemention.

The crossed-field separator method resulted in minimal pion beam spot size change and gave improvements in the e/π (μ/π) ratio of a factor of 54 (1.5) at 85 MeV/c. Additional tests at 66 MeV/c indicated a factor of 1300 improvement in the e/π ratio. It is anticipated that a crossed-field separator operating at 400 kV will be available for use in the upcoming cycles, and that its acceptance will permit use up to 50 MeV, where pion beams are relatively pure without using any special techniques.

A sampling grid scintillator has been developed for monitoring beam intensity. The scintillator has a 1% sensitive area, and intial tests indicate pileup represents only a small problem at LEP flux levels. Uncertainties are approximately 10% for absolute intensity measurements, and about 1% for relative intensity measurements. Interested users should contact D. Fitzgerald or J.D. Bowman for more information.

The working group expressed a continuing interest in having "chopped" beam capability in Area A.

Helmut Baer and Dave Bowman presented an overview of plans for a new π^o spectrometer. A proposal is being drafted which would develop a spectrometer capable of several hundred keV resolution at 100 MeV, with a design goal on a conversion point position resolution of 1mm. The design goals would represent a factor of 10 improvement in both energy resolution and data taking capability over the present π^o spectrometer. The estimated cost of the spectrometer is two million dollars.

Mike Leitch circulated a list of anticipated advantages and disadvantages of changing to a VAX 11/750 computer in the LEP counting house for data acquisition. Spokesmen are urged to consider what impact such a change might have on their experiments. Such a hardware change could be made quite quickly if desired by all users. Comments should be addressed to Mike Leitch or Tom Kozlowski (LANL, MP-1).

Dick Boudrie presented an overview on ongoing development efforts on the low energy pion spectrometer. Efforts to make the scattering chamber workable are proceeding, with some physical changes in the sliding seal system anticipated. Steps have been taken to eliminate scattering chamber/spectrometer alignment problems, and to increase the ease with which the spectrometer can be installed in the LEP cave. Spectrometer experiments will probably not run until after June to permit the completion of π^o spectrometer experiments at LEP prior to the π^o spectrometer move to

P[3]. Initial results on the nickel isotopes using the low energy pion spectrometer indicate the angle calibration is quite good. A significant (~15%) Landau tail is observed in the spectra; users are cautioned to consider what impact, if any, such a tail might have on their experiments. A liquid deuterium target is being developed and should be ready next summer. A profile monitor may also be ready for the scattering chamber which would not necessitate breaking vacuum for insertion. Modifications are also being studied which would enhance spectrometer capabilities for double-charge exchange experiments.

Dave Bowman indicated that precise beam position measurements at 160 and 230 MeV have been made and are available to interested users.

MUON SPIN ROTATION (μSR) WORKING GROUP
Arthur Denison, Chairman

Attendees: W. Bewley, University of California at Riverside
D. Wayne Cooke, Los Alamos National Laboratory
A. Denison, University of Wyoming
R. Heffner, Los Alamos National Laboratory
R. Hutson, Los Alamos National Laboratory
J. Oostens, Illinois Institute of Technology
M. Schillaci, Los Alamos National Laboratory
G. Sanders, Los Alamos National Laboratory

Both the accomplishments of the past year and their relationship to the proposed work for the coming year were discussed at the Muon Spin Rotation workshop. A new dedicated experimental setup is planned for μSR in Cave A. This beam line, as described by Dick Hutson, will include a beam chopper and spin rotator. It is envisioned that this line will be in place by early summer of 1985. Gary Sanders discussed the processes and time scale involved in setting up the ten-foot spin rotator which we will use. To do the job correctly wil probably mean the permanent rotator will not be in use until summer of 1986. Bob Heffner asked if the five-foot rotator, which is portable, could be used to do some interesting μSR physics before the permanent ten-foot rotator is functioning. The answer was that it was technically feasible but would depend on the overall pressure for its use from other groups of users. Dick Hutson discussed further details concerning the chopper work done this past year and indicated the trial runs showed the chopper performed as it should and would give an increase in useable muon rate of a factor of six over what we now have. Credit was given Stan Dodds and Grant Gist for their work in this endeavor.

Wayne Cooke described the dilution refrigerator and the experiments that were accomplished through its use. A low temperature of 105 mK was reached while on line during an experimental run. This apparatus is a powerful addition to the μSR program and has already been used to study some exotic superconducting materials of interest to the Los Alamos laboratory. Some possible improvements on the dilution refrigerator were also discussed.

Bob Heffner summarized the success of the μSR program generally over the past year and emphasized the μSR as a tool for the solid state or materials scientist has indeed been used to understand properties of materials not ameanable to other methods.

The meeting concluded with the election of Mario Schillaci to chair the μSR working group through the coming year.

NEUTRINO FACILITIES WORKING GROUP

T. A. Romanowski, Chairman

Attendees: B. Bassalleck, University of New Mexico
R. Carlini, Los Alamos National Laboratory
S. Clearwater, Los Alamos National Laboratory
B. Dieterle, University of New Mexico
T. Dombeck, Los Alamos National Laboratory
J. B. Donahue, Los Alamos National Laboratory
A. Fazely, Louisiana State University
J. Frank, Los Alamos National Laboratory
D. Huang, Temple University
N. Jarmie, Los Alamos National Laboratory
J. Mitchell, Ohio State University
C. Newsom, University of California at Los Angeles
V. Sandberg, Los Alamos National Laboratory
J. R. Sims, Los Alamos National Laboratory
E. Smith, Ohio State University
J. Stephenson, Los Alamos National Laboratory
M. Timko, Ohio State University
N. Thompson, University of California at Irvine
Keh-Chung Wang, University of California at Irvine
H. While, Brookhaven National Laboratory

The agenda contained discussions on the high intensity decay in flight neutrino facility at LAMPF, pion focusing horn, and limits on the highest possible proton beam intensity at LAMPF.

A task force to investigate the proposals for decay in flight high intensity neutrino source was established. Two sites for such a facility are possible, Line A and Line E. Excerpts from Garvey's memo defining the job for the task force are quoted below.

The criteria will be:

1) Available flux and its impact on physics and detector costs.
   a) technically
   b) operationally--including interactions with other programs
2) Value of presently installed, useful resources at each site.
3) Cost of installation at each site.
4) Review the case that the PSR duty factor is not necessary to do most of the physics.
5) Estimated cost of these programs to LAMPF and to DOE-NSF. (Who will do and pay for the physics?)
6) Comparison of the projected source performance to neutrino sources in the rest of the world.

7) Schedule

   a) for decision

   b) for construction

   c) for physics

It is important to have Line E and Line A proponents on the committee as well as neutral parties. The involvement of outside users is also important. I will act as foreman on the task force and would like the following personnel on the project:

T Division	MP Division	Outside
P. Rosen	L. Agnew	L. Auerbach, Temple University
	B. Burman	H. Chen, University of California at Irvine
P Division	J. Donahue	T. Y. Ling, Ohio State University
	J. Frank	H. White, Brookhaven National Laboratory
J. Stephensen		

In addition, the task force will confer with R. Carlini, A. Thiessen, and others in doing the job.

We believe that pursuing neutrino physics will be expensive if we are to be successful and hence, a careful evaluation of all obstacles to a successful program will be made.

The development of power supplies for a "state of the art" pion focusing horn is proceeding. Such a device is neded to maximize the neutrino flux. Design and phototyping of the horn and the associated electronics should have a high priority. At present, increased neutrino flux would benefit the data acquisition rate of Ey eriment 225. The beam requirements for neutrino physics are diverse to those for other experiments in the LAMPF program.

Neutrino physics requires intensity and a short-duty cycle whereas most of the other type of experiments, the long-duty cycle is more important than the maximum beam intensity.

It is generally believed that LAMPF is capable of delivering perhaps 20% more beam providing that the target stations and shielding can tolerate additional beam power and radiation. It was suggested that a letter should be written to Dr. P. Rosen by the chairman of the working group urging that for a first class neutrino physics experimental program, the LAMPF proton beam intensity should be brought up to its fullest capability. Several nominees for potential candidates for PAC and TAP Committees were passed to the Board of Directors. T. A. Romanowski was re-elected and will continue as chairman of the Neutrino Group for another year.

NUCLEAR CHEMISTRY WORKING GROUP
G. C. Giesler, Acting Chairman

Attendees: Rajeev S. Bhalerao, Los Alamos National Laboratory
Merle Bunker, Los Alamos National Laboratory
Gil Butler, Los Alamos National Laboratory
Bill Daniels, Los Alamos National Laboratory
Bruce Dropesky, Los Alamos National Laboratory
Gregg Giesler, Los Alamos National Laboratory
William R. Gibbs, Los Alamos National Laboratory
Jere Knight, Los Alamos National Laboratory
Mike Leitch, Los Alamos National Laboratory
Carl Orth, Los Alamos National Laboratory
James Sattizahn, Los Alamos National Laboratory
Will Talbert, Los Alamos National Laboratory
Larry Ussery, Los Alamos National Laboratory
David J. Viera, Los Alamos National Laboratory
Jan Wouters, Los Alamos National Laboratory

Anzhi Cui, Institute of Atomic Energy, Beijing, China
William B. Kaufman, Arizona State University
Chandra Pillai, Oregon State University
Jim Reidy, University of Mississippi
Peter B. Siegel, Arizona State University
Herman Wollnik, University of Giessen, West Germany

Larry Ussery was elected to be Working Group Chairman for 1985. Suggestions for new members for the TAP and PAC to represent Nuclear Chemistry were given to the User Liaison Office.

Jim Reidy of the University of Mississippi reported on a study performed at LEAR of antiproton atoms by observing x-ray emission after $\bar{p}$ capture. He studied various Mo isotopes to look for resonances resulting from the degeneracy between $\bar{p}$ x-ray levels and nuclear states, thereby leading to nuclear excitation. A resonance can couple the nuclear level to the atomic level and reduce the x-ray emission probability. The signature of this strong coupling is the disappearance of the particular x-ray. This was observed in the N=8 to N=7 transition in ^{100}Mo.

Hermann Wollnik of the University of Giessen presented an update on the time- of-flight isochronous (TOFI) spectrometer project. It is being built for mass measurements of A<70 neutron-rich nuclei far from stability. The transport line has been completed through the m/q mass filter. Preliminary particle identification data obtained with a gas ionization dE/E detector for several values of m/q was shown.

Chandra Pillai, a graduate student from Oregon State University, reported on the results of Experiment 308. This experiment is a prelude to TOFI and measures particle energy and time-of-flight in the Thin Target Area to determine masses of light, neutron-rich nuclei. Approximately 50 million events were recorded over a 4 month period and analyzed for Z and mass. The mass resolution was limited to 1-1.2% by the energy resolution. Two new mass excesses were measured for the first time: ^{20}N $\Delta=21.9\pm5.7$ MeV and ^{24}F $\Delta=8.4\pm4.5$ MeV.

Rajeev Bhalerao, a visiting staff member from India, reported on calculations performed with L.-C. Liu on pion-induced eta production. They have improved a previously developed model for this reaction at pion kinetic energies between 561 (the threshold) and 700 MeV. The development of this off-shell model lead to the discovery that the discrepancies among currently available πN phase shift analyses are mainly due to the fact that they did not properly take eta production into account.

Mike Leitch described the angular distribution measured at 50 MeV of the pion double charge exchange reaction $^{14}C(\pi^+,\pi^-)^{14}O$ to the double isobaric analog state in ^{14}O for scattering angles between 20 and 130 degrees. The energy was chosen because there is a deep minimum at that energy in the single charge exchange cross section. A strong forward peaking was observed, contrary to standard theoretical model predictions. Possible reaction mechanisms include nucleon-nucleon short range correlations and six-quark cluster mechanisms.

Anzhi Cui, a one-year visitor from Beijing, China, described the Institute of Atomic Energy, which he is from, and the work of some of the groups at the Institute.

NUCLEON PHYSICS LABORATORY (NPL) WORKING GROUP
John B. McClelland, Acting Chairman

Attendees:
R. L. Boudrie, Los Alamos National Laboratory
T. A. Carey, Los Alamos National Laboratory
S. Greene, Los Alamos National Laboratory
K. W. Jones, Los Alamos National Laboratory
N. S. P. King, Los Alamos National Laboratory
J. B. McClelland, Los Alamos National Laboratory
M. McNaughton, Los Alamos National Laboratory
O. van Dyck, Los Alamos National Laboratory

B. Aas, University of California at Los Angeles
M. Gazzaly, University of Minnestoa
G. Glass, Texas A&M University
N. Hintz, University of Minnesota
G. W. Hoffmann, University of Texas
G. Igo, University of California at Los Angeles
R. J. Peterson, University of Colorado
J. Ullman, University of Colorado
C. A. Whitten, University of California at Los Angeles

A presentation of the proposed upgrade to the NPL at LAMPF was given by J. B. McClelland. The proposal is a three- to five-year plan which includes a medium resolution spectrometer (MRS) for (p,p) and (n,p) reaction, a time-of-flight (TOF) facility for (p,n) reactions, a Line B spin precessor for independent spin compatibility in BR, and a recofiguratin of shielding in BR to increase solid angle to the np experiments. Details of the proposal are available from the MP-10 group office as document LA-10278-MS.

NPL Upgrade working groups were established for both the MRS and TOF facilities. J. B. McClelland and T. A. Carey agreed to act as temporary chairmen of the MRS and TOF working groups respectively. Users not attending the meeting may join these working groups by contacting either chairman at the Los Alamos National Laboratory.

The next meeting of the working groups is planned for mid-December of this year. Specific arrangements will be sent to the HRS, NPL, and NPL Upgrade working groups.

STOPPED MUON (SMC) WORKING GROUP

F. Mariam, Chairman

Attendees: L. Agnew, Los Alamos National Laboratory
M. Cooper, Los Alamos National Laboratory
A. Denison, University of Wyoming
R. Heffner, Los Alamos National Laboratory
C. Hoffman, Los Alamos National Laboratory
F. G. Mariam, Los Alamos National Laboratory
J. McDonough, Temple University
R. Mischke, Los Alamos National Laboratory
J. Oostens, Illinois Institute of Technology
M. Paciotti, Los Alamos National Laboratory
J. Reidy, University of Mississippi
M. W. Ritter, Stanford University
G. Sanders, Los Alamos National Laboratory
M. Schillaci, Los Alamos National Laboratory

Lewis Agnew gave a summary of the SMC beam time scheduling. In 1984, 60% of the beam was devoted to the Crystal Box experiments, which have not completed data collection. The remaining beam time was used by the μSR group and by the Yale group. In 1985, the epected usage will be as follows:

- Crystal Box ($\pi^o \rightarrow 3\gamma$) 500 hours
- Yale (muonium Lamb shift) 750 hours
- Yale (search for negative muonium) 250 hours
- μSR (including beam development) 1000 hours
- π^- x-ray 100 hours

In addition, if as expected, the water leak problem in the triplet near the A5 target proves unfixable, some or all of the experiments that are scheduled to run at the Biomed channel may have to use the SMC. The impact of this additional load on the SMC schedule is not yet known.

Gary Sanders reviewed the new additions and facilities at the SMC. The μSR group will have a dedicated experimental floor, which will be located north of the present Cave A. This group will install a 10-foot chopper-separator system, which will be operational by the end of 1985. It was also pointed out that, contingent upon the absence of a positive signal from the rare decay experiments and barring any new proposals, the Crystal Box may be removed from Cave B at the end of 1985.

Dick Hutson was elected as the new chairman of the SMC working group. The group also made eight recommendations for membership in the Program Advisory Committee (PAC).

SOLID-STATE PHYSICS AND
MATERIALS SCIENCE WORKING GROUP
Walter F. Sommer, Chairman

Attendees:		
	J. Bradbury	Los Alamos
	R. Brown	Los Alamos
	J. Cook	Los Alamos
	D. Davidson	Los Alamos
	H. Donnert	Kansas State University
	K. Dowler	Los Alamos
	D. Farnum	New Mexico Tech
	H. Frost	Los Alamos
	C. Hansen	Los Alamos
	R. Livak	Los Alamos
	B. Newman	Los Alamos
	R. Reedy	Los Alamos
	W. Sommer	Los Alamos
	M. Wechsler	Iowa State University
	J. Yu	Institute of Atomic Energy-China

M. Wechsler described the orientation of the radiation effects facility at LAMPF with the available experimental areas. He reported on the results of the calculation of the radiation damage parameters at the Los Alamos Spallation Radiation Effects Facility. Comparison of the neutron spectra at LAMPF A-6, EBR-II, and RTNS-II showed the additional high-energy spallation neutrons at LAMPF A-6. A plot of the average transferred energy was shown and the effect of electronic energy losses on the energy available for atomic displacements discussed. It was mentioned that the process of electronic energy loss will be important for non-metals. A plot of the helium production cross sections indicated the effects of spallation; there is a five-fold increase in the helium production cross section (σ_α) over the range of 20 to 800 MeV as calculated by VNMTC (Vegas-based Nucleon Meson Transport Code). The following table summarizes the results of the computer calculation for copper.

	LAMPF	EBR-II	RTNS-II
$\bar{\phi}_{total}$, 10^{17} n/m^2/s	5.5	170	0.3
$\bar{\sigma}_E$, keV-barn	54	41	300
$\bar{\sigma}_d$, barn	720	540	4010
$\bar{K}_d$, 10^{-8} dpa/s	4	92	1.2
$\bar{\sigma}_\alpha$, 10^{-3} barn	13	0.037	52
K_α, 10^{-7} appm He/s	7	0.6	1.6
K_α/K_d, appm He/dpa	18	0.07	13

The 18 appm He/dpa for LAMPF spallation neutrons compares with the 13 appm He/dpa for the first wall of a fusion reactor. Eight hundred million electron volt protons give a displacement production rate of 6.3×10^{-7} per second and a helium production rate of 6.6×10^{-5} per second. This gives 103 appm He/dpa.

D. Davidson reported on the results of the dosimetry experiment at Isotope Production Stringer 5. Comparisons were made with the previously calculated flux and spectra. Measurements were conducted in the direct proton beam and in the spallation neutron flux using 12 activation foils. The measured total neutron flux was about 5.5×10^{13} neutrons/cm^2/s/mA compared to 6.0×10^{13} neutrons/cm^2/s/mA for the calculated total neutron flux. This gives a difference of about 10%. The secondary proton flux at this location was about 10% of the total neutron flux. A review of the measured helium production and the calculated helium production shows a good agreement for 600 MeV protons on copper. The agreement is not as close for moly and stainless steel. More comparisons are being made to determine the differences in the measurements and calculations. Future plans include another dosimetry experiment at the new facility to measure neutron and proton spectra at numerous locations within the neutron and proton irradiation ports. Comparisons will then be made with the calculated flux and spectra.

W. Sommer reported on the status of the new facility. Photographs were shown of the components already built. The facility is scheduled for completion in April, 1985. At present, experiments are planned in 2 of 3 proton irradiation ports and 5 of 12 neutron irradiation ports. The deadline for new proposals is November 26, 1984. Each run cycle is expected to last 6-8 weeks with a maintenance day every 2 weeks at which time inserts can be removed and the experiments changed. Available experimental capabilities were reviewed. Along with post-irradiation testing, _in situ_ test equipment has been developed at Jülich. With the equipment, one could apply and measure a constant or a cyclic load. The experiment could determine _in situ_ stress relaxation or _in situ_ flow stress. The first run will test the radiation hardness of the equipment. The sample temperature will be controlled using a closed-loop ium system. TEM capabilities are available at LAMPF except for preparation of very radioactive TEM samples.

R. Brown reviewed experimentation at LAMPF A-6. Experiments conducted at the radiation effects facility presently include heat deposition (calorimetry) experiments. He found about 2 W/cm^3-mA which is in good agreement with the calculations. R. Brown and Jim Cost are looking at soft magnetic materials such as mumetal and amorphous metallic alloys. They found that the permeability of the mumetal dropped more rapidly than that of the amorphous alloy, such that the two permeabilities were equal after a fluence of about 3×10^{17} neutrons/cm^2. An analysis of the mechanism responsible has been accepted for publication. Experiments are also being conducted on hard magnetic materials such as Sm-Co and Fe-Nd-B to determine the magnetic field strength as a function of neutron fluence. Nuclear chemistry experiments are being done to determine cross sections.

H. Donnert reported on experiments looking at the changes (i.e., reflectivity) in laser optics components with neutron irradiation. X-ray diffraction measurements are planned to look for microstructural changes. They would like to irradiate 10-20 mirrors next summer.

During the open discussion, questions were asked about the gamma flux at LAMPF A-6. It was reported that the gamma flux will be less than 1% of the neutron flux. There was also a question concerning the future of LAMPF with the development of LAMPF II. W. Sommer reported that he felt there would be at least 6 years of radiation damage conducted at the new LAMPF A-6 facility even if LAMPF II is approved.

M. Wechsler was nominated to the TAP. R. Brown was elected as chairman of the Solid State Physics and Materials Science Working Group to replace W. Sommer in 1985.

Registration

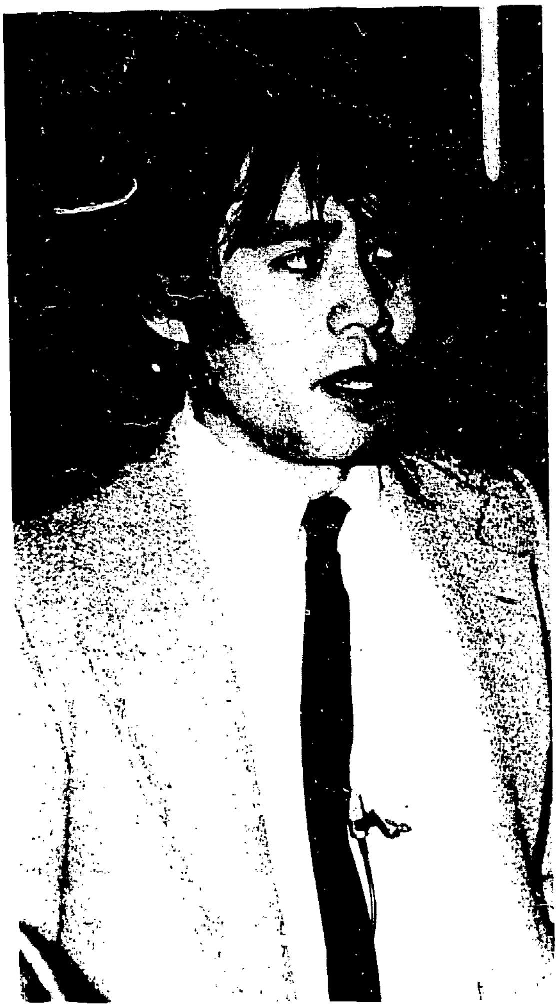
Charles Glashausser, Chairman of the LAMPF Users Group Board of Directors; Leslie Bland, winner of the Louis Rosen Prize; and Louis Rosen

Gerald Miller

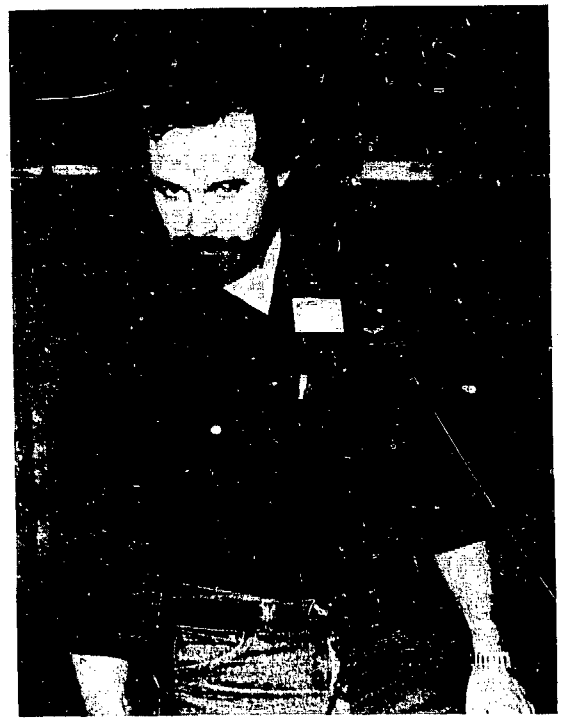
Robert Selden

Joseph Comfort and George Igo

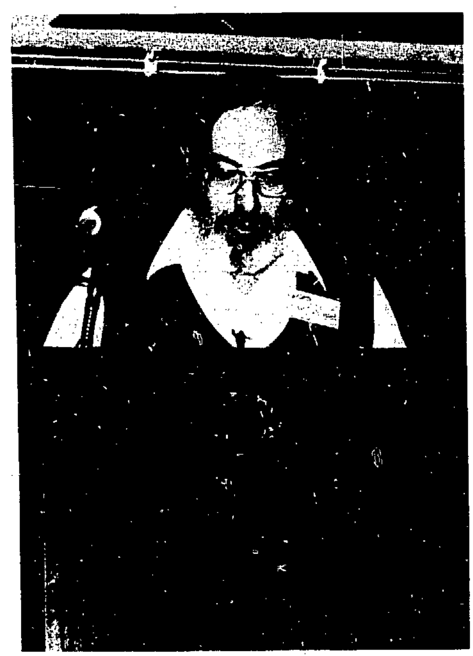
Robert Redwine



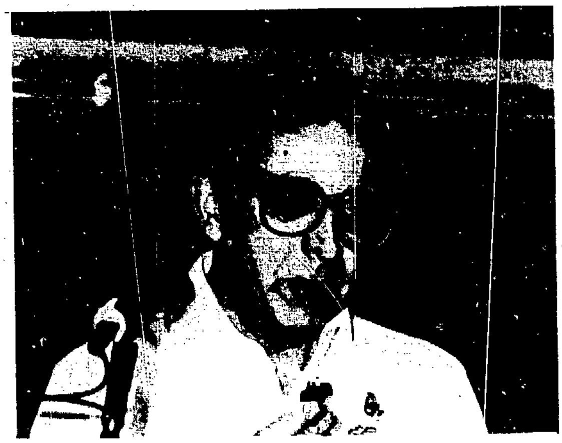
Vincent Yuan



Thomas Carey



Terry Goldman



George Igo

Don Hagerman

Wolfram Weise

Peter Riley and Louis Rosen

Charles Hollas, Peter Riley, and Louis Rosen

Arch Thiessen

Charles Glashausser

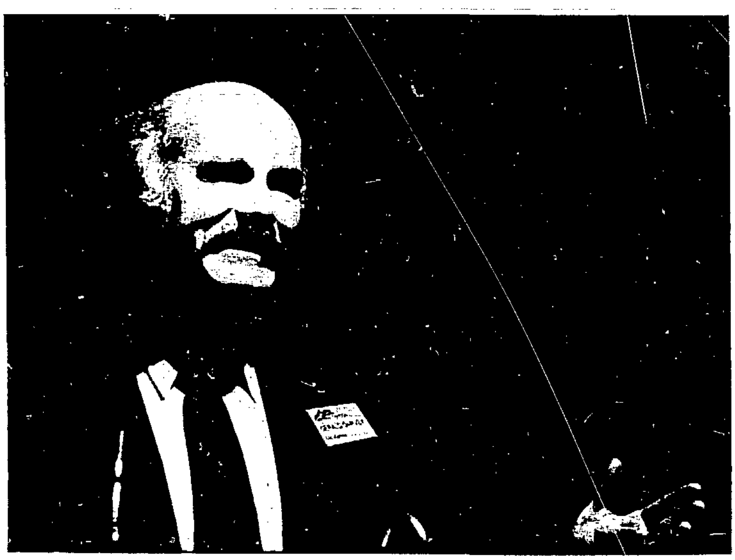
Gerald Smith

Louis Rosen and Howard Bryant

Eliazer Piasetzky

Barry Preedom

Louis Rosen



Gerald Garvey

EIGHTEENTH ANNUAL LAMPF USERS MEETING
October 29-30, 1984

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The Board of Directors consists of a Secretary/Treasurer and seven members elected by the LAMPF Users Group, Inc., whose interests they represent and promote. They concern themselves with LAMPF programs, policies, future plans, and especially with how Users are treated at LAMPF. Users should address problems and suggestions to individual Board members.

The Board also nominates new members to the Program Advisory Committee (PAC).

The 1984 membership and term expiration dates are listed below.

1986 Robert Redwine (Chairman)
Massachusetts Institute of Technology

1987 Barry Preedom (Chairman-Elect)
University of South Carolina

1985 Charles Glashausser (Past-Chairman)
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James Bradbury (Secretary/Treasurer)
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1985 Peter D. Barnes
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1986 George Burleson
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1986 Donald Geesaman
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1985 John D. Walecka
Stanford University

TECHNICAL ADVISORY PANEL (TAP) OF THE LAMPF USERS GROUP, INC.

The TAP provides technical recommendations to the Board of Directors and LAMPF management about the development of experimental facilities and experiment support activities. The TAP has 12 members, appointed by the Board of Directors, serving 3-year staggered terms. The Chairman of the Board of Directors serves as TAP chairman. The TAP membership and term expiration dates are listed below. The members shown below are the 1984 TAP members. The 1985 members will be chosen in the Spring of 1985.

1984	Billy E. Bonner Los Alamos National Laboratory	1985	Christopher L. Morris Los Alamos National Laboratory
1984	Thomas J. Bowles Los Alamos National Laboratory	1986	Michael A. Oothoudt Los Alamos National Laboratory
1986	George R. Burleson New Mexico State University	1984	Barry Preedom University of South Carolina
1984	Gerald Dugan Fermi National Accelerator Laboratory	1985	Thomas A. Romanowski Ohio State University
1985	Donald Gessaman Argonne National Laboratory	1986	Gary Sanders Los Alamos National Laboratory
1985	Kazuo Gotow Virginia Polytechnic Institute and State University	1986	Charles A. Whitten University of California, Los Angeles

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High-Resolution Spectrometer (HRS)

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University of Minnesota

Neutrino Facilities

Thomas A. Romanowski
Ohio State University

Stopped-Muon Channel (SMC)

Richard Hutson
Los Alamos National Laboratory

Nuclear Chemistry

Larry Ussery
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Energetic Pion Channel and Spectrometer (EPICS)

John Zumbro
University of Pennsylvania

High-Energy Pion Channel (P^3)

William Briscoe
George Washington University

Nucleon Physics Laboratory (NPL) Upgrade/ Medium-Resolution Spectrometer

John McClelland
Los Alamos National Laboratory

Time-Of-Flight (TOF)

Thomas Carey
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Solid-State Physics and Materials Science

Robert Brown
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Muon-Spin Rotation (μSR)

Mario Schillaci
Los Alamos National Laboratory

Low-Energy Pion Channel (LEP)

Barry Ritchie
University of Maryland

LAMPF PROGRAM ADVISORY COMMITTEE (PAC)

The PAC consists of about 25 members appointed for staggered 3-year terms. Members advise the Director of LAMPF on the priorities they deem appropriate for the commitment of beam time and the allocation of resources for the development of experimental facilities. The PAC meets twice each year for 1 week during which time all new proposals that have been submitted at least 2 months before the meeting date are considered. Old proposals, and the priorities accorded to them, may also be reviewed.

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1985

SOLID-STATE PHYSICS AND MATERIALS SCIENCE SUBCOMMITTEE

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LAMPF USERS GROUP, LUGI

Board of Directors

The LAMPF Users Group Board of Directors (BOD) met on February 17, May 25-27, and October 28-30, 1984. All meetings were chaired by Charles Glashausser; selected topics of discussion are provided below.

There were 207 registrants for the 1984 Annual Users Meeting of whom 83 were from outside the Labortory. The papers presented at the meeting and the minutes of the workshops are included in these Proceedings.

The Program Advisory Committee (PAC) met in August, 1984 and will meet again in February, 1985. For these two sessions 78 new proposals were received. The breakdown by channel follows:

HRS	23	NPL	3	SSP & MS	7
EPICS	20	SML	4	PAC AT LARGE	1
LEP	12	P^3	3		
NUC-CHEM	3	BIOMED	2		

Those PAC members whose terms usually expire at the end of 1984 will serve at the February meeting and new members for both the Technical Advisory Panel (TAP) and the PAC will be recommended by the BOD at their meeting in March, 1985. The summer meeting of the PAC will again be the "overlap" meeting.

The BOD selected Leslie Bland as the recipient of the Louis Rosen Prize for 1984. The title of the thesis is "Forward-Angle Pion Inelastic Scattering." The award was presented at the Annual Users Meeting.

The Users' lounge, located east of the Data Acquisition Center, is now furnished and functional. Comments from the User community about additions to improve its usefulness are welcome.

The BOD is concerned that some students may not be adequately covered with health insurance (accident/sickness) while working at LAMPF. Insurance possibilities at the Laboratory will be investigated and User input on this potentially serious problem is solicited.

The LAMPF-II proposal will be delivered to the Nuclear Science Advisory Committee (NSAC) and DOE in February, 1985. At the suggestion of Louis Rosen, the BOD will write support letters for LAMPF II to management in DOE and the Laboratory as well as to members of NSAC. The Science Policy Advisory Committee, formed by the BOD, provided valuable advice and significant writing assistance in the preparation of the physics justification section of the proposal.

The following workshops are scheduled to be held at LAMPF:

Nuclear Physics Laboratory Upgrades	December 17-18, 1984
Pion Double Charge Exchange	January 10-12, 1985
Dirac Approaches to Nuclear Physics	January 31 - February 2, 1985
Relativistic Dynamics and Quarks in Nuclear Physics (Summer Seminar Series)	June 3-14, 1985
LAMPF II Workshops on Experiment Definition	To be scheduled

Technical Advisory Panel

The Technical Advisory Panel (TAP) met on June 1, 1984 and October 31, 1984. During both meetings the bulk of the time was spent discussing various proposed upgrades to LAMPF capabilities during the next few years. These upgrades include:

1. High intensity polarized ion source
2. NPL improvement including buncher, beam swinger, medium-resolution spectrometer, spin precessor, and Area BR reconfiguration
3. Second-generation π^0 spectrometer
4. Crystal box upgrade for rare decay studies
5. Decay in-flight neutrino source
6. H_e jet system coupled to on-line mass spectrometer

A technical description, including detailed costing and timetable, of the implementation of a high-intensity polarized ion source has been prepared by LAMPF staff and sent to DOE. The NPL improvements were discussed in depth at a December, 1984 workshop. Design of the second-generation π^0 spectrometer and the crystal box upgrade are proceeding and will be presented at the February TAP meeting as will the choice for location of the proposed decay in-flight neutrino source.

Members of TAP have been assigned responsibility for keeping track of the various proposed upgrades and acting as liaison between the User community and LAMPF staff. Users may contact their TAP representatives if they wish to discuss issues concerning the projects. The TAP members and their respective project assignments are listed below.

NPL Upgrade	Barry Preedom, Charles Whitten
Neutrinos	Thomas Bowles, Thomas Romanowski
Computers	Donald Geesaman, Michael Oothoudt
Polarized Source	Gerald Dugan
π^0 Spectrometer II	Christopher Morris, George Burleson
Crystal Box II	Gary Sanders, Kazuo Gotow

SUMMARIES OF RECENT LAMPF PROPOSALS

Exp. 875

RADIOBIOLOGY OF PIONS

Los Alamos National Laboratory
M. R. Raju, Spokesman
A. J. van der Kogel (UNM/Los Alamos), N. Tokita, J. P. Freyer, M. A. Paciotti, P. A. Berardo

Particle radiotherapy programs (pions and heavy ions) have reached the stage of treating specific tumor sites. For pion therapy, these sites are the lower abdomen (bladder, prostate, and rectum) and the brain. With the anticipated longer survival times, the risk of developing late radiation damage in these organs increases. Therapists cannot easily change the fractionation schemes because of a fear of such late effects. However, altered fractionation schemes may be required for particle therapy, and such changes will be aided by the proposed preclinical experiments. To optimize treatment schemes for different sites, quantitative information is required on normal tissue tolerance to late-expressed damage at clinically relevant doses per fraction. The proposed project is aimed at obtaining critical biological data to support particle radiotherapy programs. The specific aims are (1) to study the tolerance to late-expressed damage of the central nervous system, lung, bladder, and rectum; (2) to measure the RBE for acute effects on the small intestine using the crypt cell survival assay; and (3) to carry out *in vitro* studies to biologically characterize different pion beams using cultured cells and spheroids. The late-effect studies are aimed at evaluating the relative importance of sublethal damage repair (by varying fraction size) and repopulation (by varying overall treatment times) in each tissue. The end points to be used will primarily involve noninvasive techniques that allow longitudinal measurement of organ function. In parallel to the functional assays, histological studies will be done to characterize different phases of damage and to identify possible target cells. The *in vitro* experiments will provide data concerning the effects of different pion beam stopping volumes on the relative biological effectiveness in a cultured cell system. Since all these experiments involve x-ray controls, our experiments are also aimed at improving understanding of conventional x-ray responses.

Exp. 876

SPIN TRANSFER MEASUREMENTS FOR *np* ELASTIC

Los Alamos National Laboratory
M. McNaughton, Spokesman
B. Bonner, J. C. Peng, N. Stein, R. York, J. McGill, D. Lee, O. van Dyck
University of Texas
P. Riley, C. Hollas
University of California, Los Angeles
G. Igo, G. Weston, B. Aas, C. Newsome

We propose to measure the spin transfer parameters K_{NN}, K_{SS}, K_{LL}, K_{LS}, and K_{SL} in $np \rightarrow np$ from 50 to 180° c.m., at 647 and 800 MeV, with an uncertainty of ±0.03.

Exp. 877

THE MICRODOSIMETRY OF ERROR INDUCTION IN MICROELECTRONICS

Clarkson College
J. F. Dicello, Spokesman
J. F. Dicello, III
Los Alamos National Laboratory
M. A. Paciotti

The probability of error induction in memory chips will be measured as a function of the energy of the incident particles and as a function of the number of memory cells per unit area for incident beams of pions, muons, and electrons. Microdosimetric spectra corresponding to the probability distribution for energy deposition in microscopic volumes will be measured with a silicon spherical proportional counter. These data will be compared with similar experimental data for neutrons to be obtained by this same group and with calculated results (1) to evaluate the relative significance of neutrons, pions, muons, and electrons for the induction of errors in electronic systems; (2) to evaluate the potential significance of stochastic variation of energy deposition in electronic components; (3) to evaluate the usefulness of pion-muon experiments for the determination of the relative contribution of nuclear secondaries and direct ionization to electronic malfunctions produced by radiation; and (4) to evaluate the usefulness of pion/muon beams for the nondestructive selection of radiation-resistant components.

Exp. 878

A SIGNATURE FOR RELATIVISTIC DENSITY SQUARED EFFECTS IN PROTON-NUCLEUS SCATTERING AT 500 AND 800 MeV

University of Texas, Austin
L. Ray and G. W. Hoffmann, Spokesmen
M. L. Barlett, R. W. Fergerson, E. C. Milner, G. Pauletta, L. Ray
Los Alamos National Laboratory
J. F. Amann, K. Jones, J. McGill

Using the HRS and beams of 500 and 800 MeV (unpolarized or n-type polarized) protons, we will determine accurate cross-section ratios for elastic scattering from the ^{54}Fe-^{48}Ca isotone pair. Using model-independent techniques and nonrelativistic (Schrodinger equation with relativistic kinematics) and relativistic (Dirac equation) microscopic models, we will analyze the experimental ratios to obtain for comparison the empirical charge density differences. These differences are expected to differ due to important density-squared contributions to the central optical potential found in the Dirac model. Since the ^{54}Fe-^{48}Ca charge density difference is already determined by electron scattering and muonic-atom measurements, the experiment will provide an absolute test of the relativistic model and of ρ^2 dependences in scattering models in general.

Exp. 879

CHARACTERISTIC DIRAC SIGNATURE IN LARGE-ANGLE $\vec{p}$ + ^{40}Ca ELASTIC SCATTERING AT 500 MeV

University of Texas, Austin
G. W. Hoffmann and M. L. Barlett, Spokesmen
R. W. Fergerson, E. C. Milner, G. Pauletta, L. Ray
Los Alamos National Laboratory
J. F. Amann, K. Jones, J. McGill

Using the HRS, we will extend the 500-MeV $\vec{p}$ + ^{40}Ca elastic differential cross section and analyzing power data from 30 to 65° center-of-momentum scattering angle. These new data will be used to compare with existing theoretical predictions of an impressive Dirac signature in the data over this angular range.

Exp. 880

LARGE ANGLE TRIPLE SCATTERING PARAMETER MEASUREMENTS FOR ELASTIC HYDROGEN AND QUASI-ELASTIC DEUTERIUM AND CARBON SCATTERING AT 800 MeV

University of Texas, Austin
M. L. Barlett and G. W. Hoffmann, Spokesmen
R. W. Fergerson, E. C. Milner, G. Pauletta, L. Ray
Los Alamos National Laboratory
J. F. Amann, B. E. Bonner, K. W. Jones, J. B. McClelland, J. A. McGill

We propose to measure the free *pp* and quasi-elastic (^{2}H and ^{12}C targets) triple-scattering parameters at 800 MeV for laboratory angles of 30, 35, 40, and 45°. The measurements will allow a determination of the *pn* triple-scattering parameters at momentum transfers where little or no data constrain the phase shifts as well as provide data that will test current models of the proton-nucleus reaction mechanisms at intermediate energies.

Exp. 881

QUASI-FREE AXIAL RESPONSE FUNCTIONS FOR LEAD AND ^{2}H USING THE $(\vec{p},\vec{n})$ REACTION

Los Alamos National Laboratory
T. A. Carey, J. B. McClelland, Spokesmen
J. F. Amann, K. W. Jones, N. S. P. King, P. Lisowski, J. A. McGill, J. M. Moss, L. Rees, N. Tanaka
Indiana University
C. D. Goodman, Spokesman
A. D. Bacher, E. J. Stephenson, T. N. Taddeucci
University of Colorado
D. A. Lind, J. R. Shepard
Ohio State University
E. Sugarbaker
Rutgers University
C. Glashausser
Tokyo Institute of Technology
H. Ohnuma

We propose to measure a complete set of polarization transfer observables for quasi-free scattering from lead and ^{2}H using the $(\vec{p},\vec{n})$ reaction. This will lead us to a direct comparison of the purely isovector axial-longitudinal $(\vec{\sigma} \cdot \vec{q})$ and axial-transverse $(\vec{\sigma} \times \vec{q})$ responses for a heavy nucleus to those for essentially free nucleons. These measurements will complement our existing data for the same set of observables obtained at the HRS via $(\vec{p},\vec{p}')$ in Exp. 741. The HRS data clearly show no difference in the axial responses for lead and ^{2}H in a region of momentum transfer where they are predicted to have sizable differences by models used to explain phenomena ranging from quenching of magnetic strengths to the low-x behavior of the EMC effect. The purely isovector axial-longitudinal response function represents new information not directly obtainable from proton, electron, or pion scattering.

Future opportunities presented by $(\vec{p},\vec{n})$ facilities at LAMPF energies for the investigation of spin-flip strength at high excitations, isovector giant resonances, individual amplitudes of the impulse approximation effective interaction, and the importance of relativistic effects in the general description of N-nucleus scattering are also discussed.

Exp. 882

MEASUREMENT OF THE DIFFERENTIAL CROSS SECTION FOR $\pi^- p \rightarrow \pi^0 n$ AT 10, 20, and 40 MeV

Los Alamos National Laboratory
J. D. Bowman, D. H. Fitzgerald, and P. A. Heusi, Spokesmen
H. W. Baer, G. O. Bolme, A. A. Browman, M. D. Cooper, D. H. Fitzgerald, F. Irom, D. M. Lee, R. J. Macek, D. E. Nagle, E. Piasetzky, U. Sennhauser
Abilene Christian University
M. E. Sadler
George Washington University
W. J. Briscoe
Temple University
V. L. Highland

We propose to measure the differential cross sections for the charge-exchange reaction $\pi^- p \rightarrow \pi^0 n$ near 0, 90, and 180° at laboratory energies of 10, 20 and 40 MeV (53, 77, and 113 MeV/c). The objective is to obtain absolute cross sections with overall uncertainties less than 10%; it may be possible to achieve 5%. The availability of (1) separated low-energy beams with contaminant-to-pion ratios of less than 50% and (2) the LAMPF π^0 spectrometer provides a unique capability for achieving such high precision in a kinematic region that is virtually devoid of measurements. The primary uncertainties in the measurement are systematic and come from the knowledge of the pion beam flux and the acceptance of the π^0 spectrometer. Accordingly, we will devote a significant portion of our effort to the measurement of these parameters, with an uncertainty of ~3% in each case. The fundamental quantity determined by the measurements is the "isospin-odd" S-wave scattering length a_0^- ($= a_0^{\frac{1}{2}} - a_0^{\frac{3}{2}}$). Our measurements will result in a direct, model-independent determination of a_0^- with an overall uncertainty <5% and perhaps as small as 2-3%. Our measurement will thus provide a stringent test of values obtained for a_0^- using a variety of indirect methods, most of which rely heavily on model calculations. More importantly, our measurements will confront models of low-energy πN interaction dynamics, specifically, the prediction for a_0^- from current algebra under the assumptions of PCAC and the soft-pion limit. The measurements of $\pi^- p \rightarrow \pi^0 n$ at 0° provide a useful test of the assumptions used in dispersion relations. Finally, the data will provide experimental constraints of the amplitudes in a region where almost no measurements now exit. In addition to the importance of these amplitudes in understanding the πN system, they also provide the basis for the study of π-nucleus interactions.

Exp. 883

A STUDY OF THE REACTION MECHANISM FOR THE $^2H(\vec{p},\gamma)^3H$ REACTION AT 800 MeV

University of South Carolina
G. S. Adams, Spokesman
G. Blanpied, B. Preedom, S. Whisnant
Gustaf Werner Institute, Uppsala, Sweden
B. Höistad, Spokesman
University of California, Los Angeles
B. Aas
Los Alamos National Laboratory
K. Jones, J. A. McGill
University of Texas, Austin
G. Pauletta

Angular distributions for the $\vec{p}d \rightarrow {}^3He\gamma$ differential cross section and analyzing power will be measured with the HRS by detecting the ^{3}He recoil particles emerging from a liquid-deuterium target. These measurements are expected to be sensitive to the meson exchange currents and N-N correlations in the ^{3}He nucleus. Hence, unique insights into the photonuclear reaction mechanism may be available.

Similar data for the reaction $\vec{p}d \rightarrow {}^3He\pi^0$ will also be obtained.

Exp. 884

PION DOUBLE CHARGE EXCHANGE ON ^{14}C AT LOW ENERGIES

Los Alamos National Laboratory

M. J. Leitch and H. W. Baer, Spokesmen

B. J. Dropesky, G. C. Giesler, L. Ussery, J. D. Bowman, R. L. Burman, M. D. Cooper, F. Irom, E. Piasetzky

Arizona State University

J. R. Comfort, J. N. Knudson

The pion double charge exchange (DCX) reaction has been of great interest since it must involve two nucleons, but at low energies ($T_\pi < 80$ MeV) it is virtually unexplored due to the expected small cross section (~ 0.2 μb/sr). The double isobaric analog transition (DIAS) is particularly interesting at forward angles near 50 MeV since the single charge exchange (SCX) isobaric analog transition (IAS) cross section there is very small, hence reducing the importance of the sequential process and emphasizing multinucleon effects. A recent measurement with the TRIUMF TPC for $50° < \theta < 120°$ yielded a cross section much higher than originally expected (~ 1 μb) with a hint of an increase toward small angles. Predictions by G. Miller show that 6-quark bag effects may cause a huge enhancement in the forward angle DCX cross section. In order to explore these questions, we propose to measure the $^{14}C(\pi^+,\pi^-)^{14}O$ (DIAS) cross section using the new Clamshell spectrometer, and extending the angular distribution over the angular range 15-130° at several energies near 50 MeV.

Exp. 885

MEASUREMENT OF K_{SS} FOR THE $\vec{p}p \rightarrow d\pi^+$ REACTION AT 650 AND 800 MeV

University of Texas, Austin

G. Pauletta, Spokesman

M. Barlett, G. W. Hoffmann

University of Minnesota

M. Gazzaly, Spokesman

Los Alamos National Laboratory

N. Tanaka, Spokesman

B. E. Bonner, J. McClelland

University of California, Los Angeles

B. Aas, G. Igo, Y. Ohashi, F. Sperisen

Gustaf Werner Institute, Uppsala, Sweden

B. Höistad

University of Udine, Udine, Italy

L. Santi, E. Waldner

We propose to measure K_{SS} for the $\vec{p}p \rightarrow d\pi^+$ reaction at 650 and 800 MeV. Deuterons will be momentum-analyzed in the HRS and dissociated by a carbon slab placed between the dipoles. The polarization of the dissociated proton will be measured by the focal-plane polarimeter of the HRS. The polarization of the dissociated proton is known to be 0.89 that of the vector polarization of the deuteron. K_{SS} has recently been identified by a partial-wave analysis (PWA) as the parameter most needed to resolve ambiguities in the PWAs above 500 MeV.

Exp. 886

MEASUREMENT OF BEAM-TARGET SPIN CORRELATION COEFFICIENTS IN ELASTIC *pd* BACKWARD SCATTERING

University of California, Los Angeles
F. Sperisen, G. Igo, Spokesmen
B. Aas, D. L. Adams, E. Bleszynski, M. Bleszynski, D. Lopiano, Y. Ohashi, C. A. Whitten, Jr.
University of Minnesota
H. Fujisawa, M. M. Gazzaly
Hiroshima University
H. Hasai, K. Iwatani
National Laboratory for High-Energy Physics, Japan
S. Ishimoto
Los Alamos National Laboratory
K. Jones, N. Tanaka
Kyoto University
A. Masaike
Nagoya University
S. Okumi
University of Texas, Austin
G. Pauletta

We propose to measure two beam-target spin correlation coefficients, $C_{SS,00}$ and $C_{LS,00}$, in backward *pd* elastic scattering by detecting the recoiling deuterons in the HRS. At $T_p = 650$ MeV we will measure an angular distribution in the c.m. range 137-180°. To determine the energy dependence of $C_{SS,00}(180°)$ we propose to measure this observable also at 500 and 800 MeV. In a recent measurement at Saclay, the deuteron tensor analyzing power $T_{20}(180°)$ was found to have large negative values and to be strongly energy dependent below $T_p = 1$ GeV. Relativistic effects are believed to be large and presently no theoretical model is close to quantitative agreement with this data. The proposed experiment will take advantage of the installation of an *S*-type polarized deuteron target for Exp. 685.

Exp. 887

PROTON-TO-DEUTERON POLARIZATION TRANSFER MEASUREMENT IN ELASTIC *pd* BACKWARD SCATTERING

University of California, Los Angeles
F. Sperisen and B. Aas, Spokesmen
D. L. Adams, E. Bleszynski, M. Bleszynski, G. Igo, D. Lopiano, Y. Ohashi, C. A. Whitten, Jr.
University of Minnesota
M. Gazzaly
Los Alamos National Laboratory
K. Jones, J. B. McClelland, N. Tanaka
University of Texas, Austin
G. Pauletta

We propose to measure the proton-to-deuteron vector polarization transfer (five independent observables), the induced deuteron vector polarization, and the proton analyzing power, in backward *pd* elastic scattering. A new technique, developed at LAMPF by Bonner et al., will be employed to measure the recoiling deuteron polarization. At $T_p = 650$ MeV, we will obtain an angular distribution in the c.m. range 137-180°. To determine the energy dependence of the transverse and the longitudinal polarization transfer coefficients at 180°, we propose to measure these observables also at 500 and 800 MeV. In a recent measurement at Saclay, the deuteron tensor analyzing power $T_{20}(180°)$ was found to have large negative values and to be strongly energy dependent below $T_p = 1$ GeV. Relativistic effects are believed to be large and presently no theoretical model is close to quantitative agreement with this data.

Exp. 888

STUDY OF THE DECAYS $\pi^+ \rightarrow e^+\nu_e\gamma$ AND $\pi^+ \rightarrow e^+e^+e^-\nu_e$

Los Alamos National Laboratory
A. Hallin, Spokesman
R. Bolton, J. D. Bowman, M. D. Cooper, J. Frank, P. Heusi, C. M. Hoffman, G. Hogan, F. Mariam, R. E. Mischke, D. E. Nagle, V. D. Sandberg, G. H. Sanders, R. Werbeck, R. A. Williams
Stanford University
S. L. Wilson, E. B. Hughes, R. Hofstadter, M. Ritter
University of Chicago
D. Grosnick, S. C. Wright
Temple University
V. Highland, J. McDonough

This experiment is a study of the decay $\pi^+ \rightarrow e^+\nu_e\gamma$, which is sensitive to the strong-interaction contributions to the pion structure. The parameter to be measured, γ, is the ratio of the axial vector to vector form factors. The present result is $\gamma = +0.44 \pm 0.12$ or $\gamma = -2.36 \pm 0.12$. We will be able to resolve this ambiguity. The improvement is possible by using the Crystal Box as the detector.

We should also be able to detect the hitherto unobserved decay $\pi^+ \rightarrow e^+e^+e^-\nu_e$

Exp. 889

CORRELATIONS BETWEEN COINCIDENT CHARGED PARTICLES EMITTED IN PION-NUCLEAR REACTIONS

Argonne National Laboratory
S. B. Kaufman, Spokesman
S. J. Sanders, B. D. Wilkins, F. Videbaek
Simon Fraser University
R. E. L. Green, R. G. Korteling
Los Alamos National Laboratory
G. W. Butler

We propose to study the mechanism by which energetic light nuclear fragments are emitted in pion-induced nuclear reactions by measuring the correlations in angle and energy of coincident charged particles. Positive and negative pions of 70 MeV will be used to bombard targets of carbon and silver, and outgoing protons, deuterons, tritons, ^3He, and ^4He will be identified in particle telescopes placed at a number of angles around the target.

Exp. 890

MEASUREMENT OF A_{LS} FOR THE REACTION $\vec{p}\vec{p} \rightarrow d\pi^+$ AT 350 AND 400 MeV

University of Texas, Austin
G. Pauletta, Spokesman
M. Barlett, G. W. Hoffmann
University of Minnesota
M. Gazzaly, Spokesman
S. Nanda
Los Alamos National Laboratory
N. Tanaka, Spokesman
K. Jones
University of California, Los Angeles
B. Aas, G. Igo, Y. Ohashi, F. Sperisen, C. Whitten
Hiroshima University
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B. Höistad
National Laboratory for High-Energy Physics, Japan
S. Ishimoto
Kyoto University
A. Masaike
Nagoya University
S. Okumi
University of Udine, Italy
L. Santi, E. Waldner

We propose to measure A_{LS} between 0 and 90° c.m. for the $\vec{p}\vec{p} \rightarrow d\pi^+$ reaction at 350 and 400 MeV. These data are needed to resolve pronounced discrepancies between theory and partial wave analysis (PWA) below 450 MeV. Measurements at these energies with polarized targets have not yet been attempted due to experimental difficulties arising from a combination of reaction kinematics and target thickness. The experimental arrangement for Exps. 583, 709, and 790 is ideally suited to overcome these difficulties. We plan to use the same apparatus as will be used for these experiments in 1985. As in the case of Exp. 790, the deuteron will be momentum-analyzed in the HRS.

We wish to point out that our facility is presently the only one capable of making these measurements without appreciable additional investment of time and money. If the opportunity is lost, it will probably be lost for good.

Exp. 891

DEVELOPMENT OF ZERO DEGREE SPIN-FLIP MEASUREMENTS AT HRS

University of Minnesota

S. K. Nanda, Spokesman

D. Dehnhard, M. Gazzaly, N. Hintz, S. J. Seestrom-Morris

Los Alamos National Laboratory

J. B. McClelland, Spokesman

T. A. Carey, K. W. Jones, J. A. McGill, C. L. Morris

Rutgers University

F. DeAngelis, E. Donahue, C. Glashausser

The measurement of polarization transfer observables at zero degree scattering angle has been highly desirable from a theoretical standpoint in our continuing effort in understanding nuclear spin excitations of lower multipolarity. Our recent spin-flip measurements for the ^{48}Ca($\vec{p},\vec{p}'$) reactions at 319 MeV strongly indicate the need for zero-degree-spin-flip measurements in identifying $M1$ strength distribution and any spreading of such strengths into higher excitations. Furthermore, such a measurement will extend our present low momentum transfer data for these nuclei, enabling a more definitive isolation of spin-excitation multipoles in the spin-flip continuum. High quality cross section spectra at zero degree have been successfully obtained for a number of nuclei, at the HRS facility. However, with the currently available polarimetry techniques at HRS, it has not been possible to carry out polarization transfer measurements at zero degree. Here, we present new techniques to extend our present zero degree experimental capability to measure spin-flip observables. The development of a new Focal Plane Polarimeter at 319 MeV to carry out such measurements is the focus of the present proposal.

Exp. 892

A STUDY OF THE (π^+,π^+d) REACTION IN ^{6}Li, ^{7}Li, ^{12}C, AND ^{13}C

University of California, Los Angeles

H. J. Ziock, Spokesman

University of Virginia

K. O. H. Ziock, Spokesman

J. R. Hurd, R. C. Minehart

We propose to measure the angular and momentum distribution for the (π^+,π^+d) reaction in ^{6}Li, ^{7}Li, ^{12}C, and ^{13}C in a coincidence experiment at the LEP channel, using a germanium detector system in the deuteron arm and the Clamshell spectrometer in the pion arm.

Exp. 893

PION SCATTERING FROM NICKEL ISOTOPES

University of Pennsylvania
H. T. Fortune and J. D. Zumbro, Spokesmen
R. Gilman, M. Dwyer, K. S. Dhuga, P. Kutt
University of Texas, Austin
S. Mordechai, C. F. Moore
Los Alamos National Laboratory/University of Minnesota
C. L. Morris
S. J. Seestrom-Morris

The proposal is to measure elastic and inelastic scattering of both π^+ and π^- from the even isotopes of nickel, in order to extract neutron and proton matrix elements for low-lying 2^+, 3^-, and 4^+ states.

Exp. 894

STUDY OF THE NEUTRON-PROTON QUADRUPOLE BOSON DENSITIES IN THE GERMANIUM REGION

Northwestern University
A. Saha, K. K. Seth, Spokesmen

Recent high resolution electron scattering results on the germanium isotopes indicate a dramatic change in the radial shape of the transition density for the second 2^+ state of ^{70}Ge, which exhibits a completely different behavior from the usual surface-peaked shape of all the other quadrupole transition densities in the even-even germanium isotopes. It is known that the nuclei in the germanium region exhibit both collective and shell aspects of nuclear structure. The IBM-2 calculations with configuration mixing are able to reproduce the basic integral properties of nuclei in this region, e.g., energy levels, B(E2)s, etc. With some additional assumptions regarding the boson transition densities, the above calculations are also able to obtain good agreement with the detailed shapes of the quadrupole transition densities including the anamolous one in ^{70}Ge. However, a basic shortcoming of these explanations is that they assume that the neutron and proton boson densities are identical. This is due to the lack of any information about isovector properties of any of the excitations in this region. We wish to rectify this by measuring angular distribution for 500 MeV proton inelastic scattering to the states in the germanium isotopes. In conjunction with electron scattering results, these data will enable us to study the isovector properties of these states and help us determine the separate proton and neutron boson densities for the two IBM-2 configurations that coexist in the nuclei in this region.

Exp. 895

STUDY OF THE IBA-2 MODEL PLUS CONFIGURATION MIXING IN THE GERMANIUM REGION

Northwestern University
A. Saha, K. K. Seth, Spokesmen

Nuclei in the germanium region exhibit both collective and shell aspects of nuclear structure. The IBA-2 Model with configuration mixing is quite successful in explaining most of the basic properties of nuclei in this region, e.g., energy levels, B(E2)s, quadrupole moments, and two neutron transfer strengths. We wish to measure the angular distribution for the states in the germanium isotopes via inelastic pion scattering at 180 MeV. This will enable us to study the isovector properties of these states and help us determine the proton and neutron boson effective charges for the two configurations of the IBA-2 Model calculations that coexist in the nuclei in this region. This, in turn, will help constrain the calculations that at present, due to lack of any such information, are forced to make the highly questionable assumption of taking the neutron and proton effective charges to be identical for all the states.

Exp. 896

A TEST OF THE DIRAC TREATMENT OF PROTON-NUCLEUS INELASTIC SCATTERING

University of Minnesota
N. M. Hintz, Spokesman
D. Cook, M. Franey, M. Gazzaly
University of Texas, Austin
G. Hoffman, M. Barlett, G. Pauletta
Rutgers University
C. Glashausser, F. DeAngelis
Los Alamos National Laboratory
J. McClelland
University of Colorado
E. Rost

We propose to test the recently developed Dirac relativistic formalism for the treatment of intermediate-energy proton-nucleus inelastic scattering. The Dirac treatment has resulted in a very considerable improvement in predictions over nonrelativistic formalisms for the elastic scattering spin observables, A_y and Q. To test the theory for inelastic transitions,it is desirable to select a state with a very simple structure, for which electron scattering form factors have been measured and, most importantly, whose excitation by protons depends strongly on the spin-dependent parts of the N-N interaction. The 6_1^+(5.13 MeV) state of ^{58}Ni satisfies these requirements in the range $T_p \simeq$ 300-500 MeV. We propose to measure σ, A_y, and D_{LS} (or D_{SL}) for this state over the range $q \simeq$ 0.8-2.2f^{-1}. Predictions for these observables, which differ considerably for the Dirac and Schrödinger treatments, are shown in the proposal.

Exp. 897

PION SINGLE CHARGE EXCHANGE IN ^7Li TO THE ISOBARIC ANALOG GROUND STATE OF ^7Be

Los Alamos National Laboratory
B. J. Dropesky, Spokesman
G. C. Giesler, M. J. Leitch, L. C. Liu, Y. Ohkubo, C. J. Orth, L. E. Ussery

We propose to determine the low-energy (35-90 MeV) portion of the excitation function for the pion single charge exchange (SCE) reaction $^7Li(\pi^+,\pi^0)^7Be$ (53-day, IAS) by activation techniques. The object is to observe the magnitude and location in energy of a dip in the excitation function caused by the interference between *s*- and *p*-wave pion-nucleon amplitudes, as we have observed for the reaction $^{13}C(\pi^+,\pi^0)^{13}N$ (10min, IAS). Our measurements of the yields of ^7Be will give the angle-integrated cross sections for the sum of the SCE reactions to the 429-keV first excited (nonanalog) state and to the 53-day isobaric analog ground state of ^7Be. We are planning to measure the former cross sections in a separate experiment at TRIUMF and the difference will yield the analog cross sections. An upward energy shift in this dip from the 60-MeV location predicted by Kaufmann and Gibbs, as was observed for ^{13}C, should provide incentive to refine the theoretical model in order to take into account the non-zero-degree contributions to the total cross section; these are more sensitive to nuclear structure effects.

Exp. 898

PION ELASTIC SCATTERING FROM ^4He — A TEST OF CHARGE SYMMETRY

Los Alamos National Laboratory
C. L. Morris, Spokesman
University of Minnesota
D. Dehnhard, S. J. Seestrom-Morris, C. L. Blilie, S. K. Nanda
University of Texas, Austin
C. Fred Moore, M. Bryan

We propose to measure $\pi^{\pm}$ elastic scattering at 140 and 260 MeV. These data in conjunction with data already taken at 180 MeV will be analyzed to obtain an estimate of the mass splitting between charge states of the Δ.

Exp. 899

A MEASUREMENT OF THE NEUTRON DEFORMATION OF ^{165}Ho BY PION SINGLE CHARGE EXCHANGE

Arizona State University
J. N. Knudson and J. R. Comfort, Spokesmen
B. G. Ritchie, V. A. Pinnick
Los Alamos National Laboratory
J. D. Bowman, Spokesman
H. W. Baer, M. D. Cooper, F. Irom, E. Piasetzky
National Bureau of Standards
H. Marshak

We propose to make an accurate determination of the neutron deformation parameter β_2^N in the highly deformed nucleus ^{165}Ho. The determination will be made by measuring $^{165}\mathrm{Ho}(\pi^+,\pi^0)^{165}\mathrm{Er}$ (IAS) differential cross sections at 0° for the holmium nuclei oriented first perpendicular and then parallel to the incident 165-MeV pion beam. Chiang and Johnson have shown that the ratio of the $\perp$ to the $\parallel$ 0° cross section is quite sensitive to the neutron deformation. They estimate in a semiclassical model

$$\frac{\partial(\beta_2^N/\beta_2^C)}{\partial A_s} = 0.5$$

where

$$A_s(\theta) = \frac{\dfrac{d\sigma^{\perp}}{d\Omega} - \dfrac{d\sigma^{\parallel}}{d\Omega}}{\dfrac{d\sigma^{\perp}}{d\Omega} + \dfrac{d\sigma}{d\Omega}}$$

We estimate that we can determine A_s with a better than 10% systematic plus statistical uncertainty leading to a 5% uncertainty in β_2^N/β_2^C.

Exp. 900

SPIN-ROTATION MEASUREMENTS ON ^{16}O AND ^{208}Pb AT 320 AND 650 MeV

University of California, Los Angeles
B. Aas, M. Bleszynski, G. Igo, Spokesmen
D. Adams, A. Azizi, E. Bleszynski, D. Lopiano, C. Newsome, F. Sperisen, A. Wang, C. A. Whitten
University of Minnesota
M. Gazzaly
University of Texas, Austin
G. Pauletta

We propose to measure the spin-rotation observables on ^{16}O and ^{208}Pb at LAMPF's HRS at 320 and 650 MeV. This would extend existing measurements on the same two nuclei at 500 and 800 MeV and provide a broader basis for the test of the Dirac phenomenology in intermediate-energy proton-nucleus scattering.

Exp. 901

RADIATIVE μ-CAPTURE IN ^3He

Boston University
J. P. Miller, B. L. Roberts, Spokesmen
E. Austin, W. van Riper, D. Whitehouse

We propose to study radiative muon capture in ^3He using the cloud muon beam in the SMC. We will measure both the photon spectrum and the angular correlation between the recoil ^3H and the photon. We will use a position sensitive, high resolution NaI (Tl) array which will provide neutron-gamma discrimination and position resolution on the photon of $\approx \pm 0.5$ cm.

Exp. 902

INELASTIC SCATTERING OF 500-MeV POLARIZED PROTONS FROM ^{88}Sr: DETERMINATION OF NEUTRON TRANSITION DENSITIES

University of New Hampshire
F. W. Hersman, Spokesman
J. R. Calarco, J. P. Connelly, J. Heisenberg, T. Milliman
Northwestern University
K. K. Seth, Spokesman
M. Arthuso, D. Barlow, G. Garino, B. Parker, A. Saha, R. Soundranayagam
Free University, Amsterdam
H. P. Blok
Los Alamos National Laboratory
J. J. Kelly

It is proposed to obtain neutron transition densities for the first two 2^+ states in ^{88}Sr by inelastic scattering of 500-MeV polarized protons. The proton scattering data will be analyzed with the density dependent effective interactions determined at this energy for $N = Z$ nuclei and with the charge densities as determined in a recent electron scattering experiment at Bates. The requirement of consistency between the results obtained from this experiment and those already obtained from a similar analysis of a recent (p,p') experiment of 200 MeV will provide a critical test of the reaction mechanism and effective interactions used.

Exp. 903

A STUDY OF TRANSITION NUCLEI IN THE RARE EARTH REGION BY PROTON INELASTIC SCATTERING

University of Minnestoa
N. M. Hintz, Spokesman
D. Cook, M. Franey, M. Gazzaly
University of Texas, Austin
G. Hoffmann, M. Barlett, G. Pauletta
Los Alamos National Laboratory
E. Shera, J. Ginocchio

We propose to measure proton elastic and inelastic scattering cross sections and, if possible, analyzing powers for three transitional rare earth nuclei (^{150}Nd, ^{154}Gd, and ^{192}Os) at any energy between 650 and 800 MeV. The purpose of the experiment is to obtain isoscalar multipole transition moments for 4-6 of the low-lying rotational and vibrational states in each nuclei. The data will provide a test of various structure models, such as the IBA-II, and recently developed multistep reaction theories. In all three cases, electron scattering and other electromagnetic data exist that cannot be understood in terms of the simple IBA-I model. To test IBA-II (neutron and proton bosons), both neutron and proton matrix elements are needed, which this experiment [in conjunction with (e,e')] will provide. An energy resolution in the range 60-75 KeV is required. Either polarized or unpolarized beam can be used.

Exp. 904

MASS DEPENDENCE OF NONANALOG DCX

University of Pennsylvania
H. T. Fortune, R. Gilman, Spokesmen
K. S. Dhuga, M. Dwyer, J. Zumbro
Indiana University
L. C. Bland
New Mexico State University
G. R. Burleson, J. Faucett
University of Texas, Austin
C. F. Moore, S. Mordechai, P. A. Seidl

We propose to continue the investigation of the N, Z, and A dependence of nonanalog DCX on more massive nuclei.

Exp. 905

ELASTIC AND INELASTIC SCATTERING OF $\pi^{\pm}$ ON ^3H AND ^3He TO TEST CHARGE SYMMETRY, COMPARE FORM FACTORS, AND INVESTIGATE THE REACTION MECHANISM

University of California, Los Angeles
B. M. K. Nefkens, Spokesman
S. Adrian, A. D. Eichon, J. M. Engelage, G. J. Kim, A. A. Mokhtari, J. A. Wightman, H. J. Ziock
George Washington University
W. J. Briscoe, M. Taragin, C. J. Seftor
Abilene Christian University
M. E. Sadler
Los Alamos National Laboratory
R. Boudrie, C. L. Morris

We propose to measure π^+ and π^- scattering on ^3H and ^3He at five energies in the range $T_\pi = 141$ to 296 MeV for $\theta_\pi = 30$ to 117°. We want to investigate simultaneously, elastic and inelastic scattering slightly above nuclear breakup. The objectives are:

(1) To probe the nature and extent of charge symmetry breaking as manifested in the deviation from unity of the superratio,

$$R \equiv d\sigma(\pi^+\ ^3H)\, d\sigma(\pi^-\ ^3H) / d\sigma(\pi^+\ ^3He)\, d\sigma(\pi^-\ ^3He).$$

Recently, we reported[1] that $R = 1.31 \pm 0.09$ for $T_\pi = 180$ MeV at $\theta_\pi = 60°$ for elastic scattering; R is consistent with unity for inelastic scattering. As electromagnetic effects are small, $R \neq 1$ implies a violation of nuclear charge symmetry.

(2) To probe the effective πN energy for use in π^3H scattering theories. There is a minimum or dip in $d\sigma(\pi^-\ ^3H)$ and $d\sigma(\pi^+\ ^3He)$ *elastic* scattering near $\theta = 70°$ because the spin flip transition is small. A precise determination of the off-mass shell πN energy is sensitive to the angle at which the dip occurs and, thus, affects the otherwise parameter-free first-order pion-nucleon optical potential calculations.

(3) To compare the ^3H, ^3He, and ^4He form factors. In the vicinity of 70° a comparison of $d\sigma(\pi^+\ ^3H)$ with $d\sigma(\pi^-\ ^3He)$ elastic scattering is a comparison of the spin form factors of ^3H and ^3He; similarly, outside 70° the mass form factors are compared. Finally, coupling these results with existing data on $d\sigma(\pi^+\ ^4He)$ provides an interesting comparison of the form factors and radii of ^3He and ^4He.

Exp. 906

DCX ON ^{44}Ca

University of Pennsylvania
H. T. Fortune, R. Gilman, Spokesmen
K. S. Dhuga, M. Dwyer, S. Mordechai, J. Zumbro
Indiana University
L. C. Bland
New Mexico State University
G. R. Burleson, J. Faucett
University of Texas, Austin
C. F. Moore, P. A. Seidl
Los Alamos National Laboratory
C. L. Morris

We propose to complete the study of pion double charge exchange on the calcium isotopes with measurements on ^{44}Ca.

Exp. 907

SPIN EXCITATIONS IN ^{40}Ca AND ^{48}Ca

Rutgers University
C. Glashausser, Spokesman
F. DeAngelis, E. Donoghue
Los Alamos National Laboratory
K. Jones, Spokesman
J. McClelland, J. Moss
University of Minnesota
S. Nanda, Spokesman
D. Dehnhard, F. Franey, M. Gazzaly, N. Hintz, S. Seestrom-Morris

The spin-flip cross section σS_{nn} will be measured for ^{40}Ca and ^{48}Ca at 319 MeV at the HRS over the excitation energy region from 6 to 40 MeV from 2.5 to 10°. A multipole decomposition of the data will determine the contribution of orbital angular momentum transfers 0, 1, and 2. Comparison of ^{48}Ca and ^{40}Ca is a sensitive indicator of possible spreading of the *M1* strength in ^{48}Ca, and of predicted differences in the strengths of the higher multipoles due to effects ofthe neutron excess. The total time required is 228 hours.

Exp. 908

ANGULAR DISTRIBUTION FOR THE ^{42}Ca(π^+,π^-)^{42}Ti (g.s.) REACTION AT 290 MeV

Northwestern University
K. K. Seth, Spokesman
Northwestern University Group
Los Alamos National Laboratory
M. O. Kaletka

It is proposed to measure the angular distribution for the double analog transition in the DCX reaction ^{42}Ca(π^+,π^-)^{42}Ti (g.s.) at $T(\pi) = 290$ MeV in order to test the predictions of the coupled channel theory of Liu. The results of this theory have already been verified at 180 MeV where a large shift in the position of the minimum and a very large enhancement of the forward angle cross section was predicted. At 290 MeV relatively small enhancement and essentially no shift in the position of the minimum are predicted. It is important to determine if the theory is equally successful at this energy.

Exp. 909

EXCITATION FUNCTIONS FOR THE $\pi^+d \to pp$ REACTION

Northwestern University
K. K. Seth, Spokesman
Northwestern University Group

It is proposed to measure the excitation functions for the differential cross sections for the basic pion production reaction $\pi^+d \to pp$ at three angles θ(c.m.) ≈ 24, 48, and 72° in the energy range $T(\pi) = 50$ to 300 MeV. It is shown that these measurements will provide a unique set of data for this important reaction and will resolve many long standing discrepancies in the existing data.

Exp. 910

STUDY OF THE ANALOG DCX TRANSITION $^{88}Sr(\pi^+,\pi^-)^{88}Zr$ (17.2 MeV)

Northwestern University
K. K. Seth, Spokesman
Northwestern University Group

Detailed experimental studies of analog DCX transitions have so far been made only on nuclei with $A < 60$. No excitation function measurements or angular distribution measurements for heavier nuclei exist. In a recent experiment we have obtained such a good signal/background ratio for the reaction $^{88}Sr(\pi^+,\pi^-)^{88}Zr$ (17.2 MeV) that it appears completely feasible to make excitation function and angular distribution measurements on this transition. We propose to make these measurements.

#911 "A Systematic Study of π^+ and π^- Scattering to 2_1^+ States in Ni, Zn, Ge, and Se" by J. D. Zumbro, University of Pennsylvania, S. J. Seestrom-Morris, University of Minnesota, and H. T. Fortune, University of Pennsylvania, spokespersons.

Participants:
Indiana University: L. C. Bland
New Mexico State University: K. S. Dhuga, J. A. Faucett.
University of Pennsylvania: M. Dwyer, H. T. Fortune, and R. Gilman
University of Texas: C. F. Moore, S. Mordechai, and P. A. Seidl.
Los Alamos: C. L. Morris

We propose to measure π^+ and π^- scattering over the first maxima in the angular distributions of the first 2^+ states in the nuclei ^{58,60,62,64}Ni, ^{64,66,68,70}Zn, ^{70,72,74,76}Ge, and ^{76,78,80,82}Se. These measurements will permit us to extract $R=\sigma(\pi^+)/\sigma(\pi^-)$ to allow the determination of the M_n/M_p for the $0^+ \rightarrow 2_1^+$ transition in these nuclei by normalizing DWIA calculations to the data. These measurements will provide systematic nuclear structure information about the neutron and proton matrix elements to the first 2^+ state over a region of collectivity between a closed proton and neutron shell (Z=28,N=28) and approaching a closed neutron shell (N=50).

#912 "Transverse Elastic Scattering of Pions from Odd-Mass Targets" by R. J. Peterson, University of Colorado, spokesman.

Participants:
University of Colorado: P.W.F. Alons, B. Clausen, J.H. Mitchell, J.J. Kraushaar, R.J. Peterson, R.A. Ristinen, J.L. Ullmann
New Mexico State University: G. Burleson, K. Dhuga, J. Faucett, G. Kyle
Los Alamos: W. Cottingame, S. Greene

Comparison of elastic pion scattering from odd and even mass targets is proposed for the EPICS system under kinematic conditions that enable the isolation of the transverse spin-transfer component by varying T_π and θ to maintain a constant momentum transfer. Both π^+ and π^- beams will be used to extract the isoscalar and isovector cross sections. These results will be sensitive to the damping of magnetic multipole moments for the very clean case of nuclear ground states, previously examined in detail by elastic electron scattering.

#913 "Pion Charge Exchange to a Spin Excitation, Using the Reaction $^{14}N(\pi^+,\pi^0)^{14}O$" by R. J. Peterson, University of Colorado, spokesman.

Participants:
University of Colorado: P.W.F. Alons, B.L. Clausen, J.J. Kraushaar, J.H. Mitchell, R.A. Ristinen, J.L. Ullmann
Los Alamos: H.W. Baer, M.D. Cooper, F. Irom
Arizona State University: J. Knudson

It is proposed to use the π^0 spectrometer on the LEP line to measure the peak differential cross section for the ground state in the $^{14}N(\pi^+,\pi^0)^{14}O$ reaction at beam energies from 100 to 300 MeV. The bump seen near a beam energy of 160 MeV for 1^+ inelastic scattering will be examined in the charge exchange mode to learn more on the propagation of deltas in nuclear matter in the intermediate state of the reaction.

#914 "Measurement of the Analyzing Power of a Muon Polarimeter for Use in a Search for Muon Polarization in the Decay $K_L \rightarrow \mu\mu$" by G. H. Sanders and W. W. Kinnison, Los Alamos, spokesmen.

Participants:
UCLA: R.D. Cousins, P. Melese, W. Slater
Los Alamos: J.S. Frank, D.M. Lee, R. McKee, Jr.
University of Pennsylvania: W.R. Molzon, W.D. Wales
Princeton University: J.F. Greenhalgh
Stanford University G. Bonneaud, G.M. Irwin, J. Margulies, J. Martoff, D. Ouimette, J.L. Ritchie, S.G. Wojcicki
Temple University: L.B. Auerbach, V.L. Highland, W.K. McFarlane
College of William and Mary: M. Eckhause, P. Guss, D. Joyce, J. Kane, W. Vulcan, R. Welch, R. Whyley

We propose to measure the analyzing power of a portion of a large, segmented muon polarimeter using the LAMPF Stopped Muon Channel. The full polarimeter will be used in a program of research which will study several rare kaon decays using a neutral kaon beam at the Brookhaven National Laboratory AGS. The exceptional capability of the LAMPF Stopped Muon Channel, which can provide intense, controllable beams of polarized decay muons is ideal for this essential measurement. Without a detailed measurement of the polarimeter analyzing power the search for muon polarization in the known process $K_L \rightarrow \mu\mu$ would not be credible.

#915 "Double β-Decay Matrix Elements for ^{128}Te and ^{130}Te from Nonanalog DCE Reaction" by A. Fazely, Louisiana State University, spokesman.

Participants:
Los Alamos: L.C. Liu
Ohio State University: E. Smith, M. Timko

We propose to measure non-analog DCE cross sections for ^{128}Te and ^{130}Te to extract nuclear matrix elements for double β-decay of these nuclei.

#916 "Nuclear Information from Small Angle p-Nucleus Elastic Scattering" by G. Igo, M. Bleszynski, and E. Bleszynski, UCLA, spokespersons.

Participants:
UCLA: B. Aas, F. Sperisen, Y. Ohashi, C. Whitten, D. Adams, M. Moshi

We propose to measure the phase of the nuclear amplitude at $\Theta = 0^0$ i.e., $\mathrm{Re}|f(0)|$. This measurement can be done at small angles in the Coulomb-nuclear region, i.e., the differential cross sections. Application of multiple scattering theory calculations with and without the relativistic pair term has shown that the Dirac impulse approximation has a very sensitive effect on the ratio $\mathrm{Re}|f(0)|/\mathrm{Im}|f(0)|$ which is measured in the experiment. We propose to test the Dirac impulse approximation very thoroughly by measuring all possible observables.

#917 "Pion Charge Exchange to Delta-Hole States of Complex Nuclei," by R. J. Peterson, University of Colorado, spokesman.

Participants:
University of Colorado: P.W.F. Alons, B.L. Clausen, J.J. Kraushaar, R.A. Ristinen, J.L. Ullmann
Los Alamos: H.W. Baer, J.D. Bowman

It is proposed to use the π^0 spectrometer on the P^3 beam line at a pion energy of 450 MeV to examine the broad states near an excitation of 300 MeV formed by the (π^+,π^0) and (π^-,π^0) reactions on complex nuclei. Such pion charge exchange will excite the transverse spin response in the delta-hole region of excitation. Recent calculations show that this response is sensitive to the dynamical interaction of the delta in its nuclear environment.

#918 "Study of the Microscopic Structure of the Calcium Isotopes" by A. Saha, University of Virginia and J. J. Kelly, University of Maryland, spokesmen.

Participants:
University of Virginia, University of Maryland, LAMPF

Considerable progress has been made in recent years in making precise determinations of neutron and proton transition densities of nuclear states by making use of a variety of probes. Recent results from intermediate energy electron and proton scattering experiments on ^{16}O and ^{18}O have successfully demonstrated the efficacy of this method in determining the microscopic nuclear structure of states in these nuclei. We wish to do the same for the calcium isotopes. The purpose of this proposal is twofold: (i) As part of a great investigation into determining the complete nuclear structure of states in the calcium isotopes, by making use of intermediate energy electron and proton scattering experiments. The requisite electron scattering data on ^{40}Ca and ^{48}Ca exists; we have proposed to do the same for the other calcium isotopes at NIKHEF. (ii) To make a systematic study of the effective interaction between intermediate energy protons and nuclei, and test the validity of the Local Density Approximation. The comparison of these experiments will test this hypothesis independent of the accuracy of the nuclear matter theory.

#919 "Microscopic Structure of s-d Shell T=1 Nuclei" by A. Saha, University of Virginia and J. J. Kelly, University of Maryland, spokesmen.

Participants:
University of Virginia, University of Maryland, LAMPF

We wish to make a consistent detailed study of the microscopic nuclear structure of the low-lying states in the T=1 nuclei: ^{26}Mg, ^{30}Si, ^{34}S. We plan to do this by determining their separate proton (ρ_p) and neutron (ρ_n) transition densities from medium energy electron and proton scattering studies. We are proposing here to do the corresponding proton scattering experiments on these nuclei.

#920 "Study of the ^{3}He(π^-,π^0p) Reaction by Detecting Neutral Pions and Protons in Coincidence" by S. Gilad, MIT and E. Piasetzky, Tel Aviv University, spokesmen.

Participants:
MIT: W.J. Burger, G.W. Dodson, S. Hoibraten, R.P. Redwine
Los Alamos: H.W. Baer, J.D. Bowman, F.H. Cverna, M.J. Leitch
Tel Aviv University: J. Alster, D. Ashery, J. Lichtenstadt, M.A. Moinester, S.A. Wood
Weizmann Institute: Z. Fraenkel
University of Virginia: R. Minehart, C. Smith, R. Whitney
SIN: G.S. Kyle

We propose a coincidence measurement of the ^{3}He(π^-,π^0p) reaction. Neutral pions will be detected with the π^0 spectrometer; protons will be detected with an array of eight plastic scintillator ΔE-E telescopes. The measurement will be done at a pion laboratory scattering angle of 120°, and at an incident pion energy of 245 MeV.

The (π^-,π^0p) reaction is not a direct process in which the pion interacts with a single nucleon in the nucleus. At least two nucleons must be involved in this process, as in the pion double charge exchange reaction. In the intermediate energy region, where Δ-dominance can be assumed, the (π^-,π^0p) reaction can provide direct information on the Δ-N interaction in the nucleus. ^{3}He is particularly suitable as a target since it is relatively simple, there is an expected enhancement of the Δ-N process, and it is being extensively studied experimentally.

#921 "Study of the ^3He, ^3H (π^+, π^op) Reactions by Detecting Neutral Pions and Protons in Coincidence" by S. Gilad, MIT and E. Piasetzky, Tel Aviv University, spokesmen.

Participants:
MIT: W.J. Burger, G.W. Dodson, S. Hoibraten, R.P. Redwine
Los Alamos: H.W. Baer, J.D. Bowman, F.H. Cverna, M.J. Leitch
Tel Aviv University: J. Alster, D. Ashery, J. Lichtenstadt, M.A. Moinester, S.A. Wood
Weizmann Institute: Z. Fraenkel
University of Virginia: R. Minehart, C. Smith, R. Whitney
SIN: G.S. Kyle

We propose a coincidence measurement of the $^3He(\pi^+,\pi^o p)$ and $^3H(\pi^+,\pi^o p)$ reactions. Neutral pions will be detected with the π^o spectrometer; protons will be detected with an array of eight plastic scintillator ΔE-E telescopes. The measurement will be done at three laboratory pion angles, for an incident pion energy of 245 MeV.

The $(\pi^+,\pi^o p)$ reaction is expected to be mainly a process in which the pion interacts with a single nucleon in the nucleus (quasi-free scattering). In the intermediate energy region one can assume this process, to be the excitation of a Δ, followed by its decay. However, this reaction also involves competing processes in which the Δ interacts in the nucleus. By performing the proposed measurement on two relatively simple 3-body systems, we hope to understand better the competition between the quasi-free process and the competing processes in which the Δ interacts in the nucleus. In particular, the $^3He(\pi^+,\pi^o p)$ reaction will enhance a competing process involving the Δ-N interaction in the nucleus.

#922 "DCX on Light Nuclei" by G. R. Burleson, New Mexico State University and H. T. Fortune, University of Pennsylvania, spokesmen.

Participants:
Los Alamos: C.L. Morris
New Mexico State University: K.S. Dhuga, J. Faucett
University of Pennsylvania: R. Gilman, J.D. Zumbro
University of Texas: C.F. Moore, S. Mordechai

We propose to better examine nonanalog DCX on light targets to unbound residual states.

#923 "Pion Double Charge Exchange on ^{20}Ne, ^{22}Ne, and ^{40}Ar" by S. Mordechai, University of Texas and H. T. Fortune, University of Pennsylvania, spokesmen.

Participants:
Indiana University: L.C. Bland
University of Texas: M.K. Brown, C.F. Moore, S. Mordechai, P.A. Seidl

New Mexico State University: G.R. Burleson, K.S. Dhuga, J.A. Faucett, G.S. Kyle
University of Pennsylvania: M. Burlein, R. Gilman, P. Kutt, J.D. Zumbro
Los Alamos: C.L. Morris

We propose to measure the DCX reaction on ^{20}Ne, ^{22}Ne, and ^{40}Ar. The measurements will include forward-angle excitation functions on all three targets in the energy range of 120-292 MeV and two angular distribution measurements on ^{40}Ar at 164 and 292 MeV. The DCX reaction on ^{40}Ar will allow simultaneous observation of the double-isobaric-analog and nonanalog transitions to 0^+ states in the same nucleus. ^{40}Ar is the lightest available target with T=2, and thus can provide valuable information on the isospin dependence of the second-order pion nucleus optical potential. The measurements of the DCX on ^{20}Ne and ^{22}Ne are needed for better understanding of the behavior of the nonanalog transitions on T=0 nuclei and the analog transitions on T=1 nuclei respectively.

#924 "Cross Sections and Analyzing Powers for Elastic and Inelastic Scattering of Protons from ^{15}N" by S. J. Seestrom-Morris, University of Minnesota and K. W. Jones, Los Alamos, spokespersons.

Participants:
Los Alamos: J.F. Amann, L. Bimdot, G.C. Idzorek
University of Pennsylvania: J.D. Zumbro
University of Minnesota: S. Nanda, M. Gazzaly
Rutgers University: C. Glashausser, R.W. Fergerson, A. DeAngelis

We propose to measure cross sections and analyzing powers for elastic and inelastic scattering of polarized protons from ^{15}N. The measurements will be made at 550 MeV where the nucleon-nucleon (NN) interaction is well known and where the impulse approximation is expected to be valid. These data will be compared with microscopic distorted wave impulse approximation calculations. Special emphasis will be placed on M4 transitions recently identified in a pion scattering experiment.

#925 "Measurement of M_n and M_p for Transitions to States in ^{28,30}Si and ^{32,34}S" by C. L. Morris, Los Alamos, spokesman.

Participants:
University of Minnesota: D. Dehnhard, S.J. Seestrom-Morris
University of Pennsylvania: J.D. Zumbro
University of Virginia: A. Saha
University of Texas: C.F. Moore, S. Mordechai
Los Alamos: K.W. Jones

We propose to measure inelastic $\pi^{\pm}$ scattering from the low-lying states in ^{28,30}Si and ^{32,34}S. Special emphasis will be placed on careful (≈2%) normalizations. Data will be taken at T_π=180 MeV, and at laboratory scattering angles between 25^{o} and 80^{o}. These data will be used to provide more information about Coulomb mixing in nuclei.

#926 "A Study of 'Stretched' M4 Transitions in p-Shell Nuclei Using Intermediate Energy Polarized Protons" by S. J. Seestrom-Morris, University of Minnesota and K. W. Jones, Los Alamos, spokespersons.

Participants:
University of Minnesota: M. M. Gazzaly, S. K. Nanda, S. J. Seestrom-Morris
Rutgers University: A. DeAngelis, C. M. Glashausser, R. W. Fergerson
Los Alamos: J. F. Amann, L. Bimbot, G. C. Idzorek

We propose to study the stretched M4 excitations in the p-shell nuclei with intermediate energy polarized protons of energy 550 MeV. Many of these states have been studied through both inelastic electron and pion scattering, but little is known about proton-induced excitations. Other probes have done much to establish the proton/neutron character of these transitions. We have determined that the Wolfenstein parameter $D_{\ell s}$ is particularly sensitive to the proton/neutron character of the transition density. Measurement of this parameter would thus provide a test of the reaction mechanism and models describing intermediate energy proton scattering. We propose to study the M4 excitations in ^{12}C, ^{13}C, ^{15}N, and ^{16}O to establish a systematic database for this study.

#927 "Investigation of Non-Analog Double Charge Exchange Between 50 MeV and 120 MeV" by J. A. Faucett, New Mexico State University and J. D. Zumbro, University of Pennsylvania, spokesmen.

We propose to measure the nonanalog transitions for ^{12}C, ^{16}O, ^{40}Ca, and ^{56}Fe. ^{12}C, ^{16}O, and ^{40}Ca are T=0 nuclei and in each case the transition of interest leaves the residual nucleus in the ground state. ^{56}Fe is a T=2 nucleus, with a nonanalog transition to the ground state of ^{56}Ni. All four of these transitions have had angular distributions and excitation functions measured at energies of 120 MeV and above (and excitation functions down to 101 MeV for ^{16}O and to 80 MeV for ^{56}Fe). See Figs. 1 to 4 for the existing excitation functions. All four nonanalog transitions show excitation functions which peak in the region of 140 to 180 MeV, the peak centroid moving down in energy as A increases.

#928 "$\vec{p}$ + n Quasielastic Scattering from Deuterium" by M. L. Barlett and G. W. Hoffmann, University of Texas, and J. B. McClelland, Los Alamos, spokesmen.

Participants:
Los Alamos: J. F. Amann, B. E. Bonner, J. B. McClelland, M. W. MacNaughton
University of Texas: R. W. Fergerson, C. L. Hollas, E. C. Milner, G. Pauletta, P. J. Riley.

We will measure quasielastic $\vec{p}$ + n triple scattering parameters, D_{ij}, (Wolfenstein parameters) using a liquid deuterium target at 650 and 800 MeV. The center-of-momentum angular range will be 50° - 120° at 800 MeV, and 30° - 120° at 650 MeV. These new data will allow a better determination of the I = 0 phase shift solutions at these energies.

#929 "Crack Growth in 800 MeV Proton and Neutron Irradiated Alloy 718" by R. D. Brown, Los Alamos, spokesman.

Participants:
IAE, China: J. Yu
Los Alamos: W. F. Sommer

The use of alloy 718 in the LAMPF beam line window makes knowledge of crack growth rates in this alloy of importance to LAMPF, particularly with respect to a decision on how often this window should be replaced so as to minimize chances of window failure through crack propagation. We propose that a total of 36 samples of alloy 718 be irradiated. Twelve of these samples would be neutron irradiated to the same displacement per atom level (about 0.5 to 1 dpa) as twelve samples which would be proton irradiated. The primary difference in these two batches of samples would be the greater helium levels produced in the proton irradiated (about 55 appm He) as compared to the neutron irradiated (about 10 appm He). Testing of these two batches of samples would give some indication of effects of helium contents on crack propagation rate and whether it modifies the propagation mechanisms. It is proposed that a third group of twelve samples be proton irradiated for at least 100 days (about 10 dpa) to determine whether the higher damage levels enhance the crack growth rate. Both irradiation and testing will be performed at two temperatures: room temperature and 400°C. The low temperature irradiations should emphasize mechanisms involving hardening and embrittlement, while the higher temperature should allow helium migration during irradiation.

#930 "Radiation Damage in Samarium-Cobalt Permanent Magnets" by R. D. Brown and J. R. Cost, Los Alamos, spokesmen.

Participants:
Arizona State University: J. T. Stanley
University of Dayton: K. J. Strnat, H. F. Mildrum (UD Research Institute)
Iowa State University: M. S. Wechsler
Los Alamos: W. F. Sommer

The current proposal to study the degradation of the magnetic field strength of Sm-Co magnets has been revised to allow for better pre-irradiation characterization of the magnets and more post-irradiation studies. In addition to measurements of Sm-Co magnets, we will try to include some of the newer Fe-Nd-B magnets in our study.

We propose to extend earlier calculations of radiation damage rates in copper from the LAMPF neutron flux to the samarium-cobalt system. Together with the results from neutron activation foil measurements, this will allow us to determine the number of displacements per atom in the magnets.

#931 "Radiation Effects in Optical Materials for the Free Electron Laser" R. D. Brown and B. E. Newnam, Los Alamos, spokesmen.

Participants:
Los Alamos: W. F. Sommer, D. R. Davidson

The free electron laser uses an electron beam, the outer fringe of which interacts with a graphite "scraper" prior to being injected into the laser cavity. This interaction produces a spectrum of gammas as well as neutrons. The electron energy can be as low as 5 MeV and as high as 120 MeV with present operation at 20 MeV. Mirrors for use at the free electron laser can be damaged by the combined gamma and neutron fluxes, and it is therefore useful to study the nature of the damage formed and its effect on the mirrors' reflectivity.

We propose that the neutron energy spectrum generated at the free electron laser (FEL) be measured using activation foils and the data unfolded using available computer codes. In addition we need information on the effectiveness of gammas and neutrons in producing displacement damage in the candidate materials so as to ascertain the relative importance of each to the production of displacements.

#932 "Radiation Damage in Magnetically Soft Crystalline and Amorphous Alloys" by R. D. Brown and J. R. Cost, Los Alamos, spokesmen.

Participants:
Arizona State University: J. T. Stanley
Los Alamos: C. F. Hansen

Previous work on the amorphous metallic alloy 2605S-3 and the crystalline alloy Mumetal has allowed us to analyze the initial permeability decay curves. The results of this analysis showed that the permeability decay could be considered to consist of two stages, the first occurring at a relaxation fluence of about 1×10^{17} n/cm^2, the second at about 4×10^{17} n/cm^2. These two fluences were very nearly the same for both the crystalline and the amorphous alloy. We propose to irradiate additional samples to investigate the transient increases in the permeability which we observed after certain applied fields in the earlier experiments. Investigation of these transients and their decay under irradiation should provide additional information on point defect kinetics in the amorphous alloys and further help to determine the mechanisms for irradiation-induced permeability decay. An additional set of larger toroid samples will be irradiated to check that the permeability decay is in agreement with that measured previously in the small test toroids. If the earlier findings hold, serious consideration can be given to the use of amorphous 2605S-3A toroids for beam current monitors at LAMPF. These would be desirable in areas such as A-6, where radiation levels degrade the present Mumetal toroids in a few weeks.

#933 "Study of the Mass and Energy Dependence of Ultra Low Energy Pion Single Charge Exchange" by F. Irom and J. D. Bowman, Los Alamos, spokesmen.

Participants:
Los Alamos: H. W. Baer, D. H. Fitzgerald, P. Heusi, M. J. Leitch
George Washington University: W. J. Briscoe
Abilene Christian University: M. E. Sadler
Utah State University: S. H. Rokni
Catholic University: H. Crannell, D. I. Sober
Arizona State University: J. N. Knudson

We propose to measure the energy dependence of the zero-degree pion single charge-exchange cross section to the isobaric analog state for ^{15}N and ^{120}Sn, at pion energies 10, 20, and 30 MeV. The objective is to obtain absolute cross sections with overall uncertainties less than 10%. The availability of separated ultra-low-energy beams with contaminant-to-pion ratios less than 50% and the LAMPF π^0 spectrometer provide a unique capability for achieving such measurements.

#934 "Inclusive (π,η) Reactions in Nuclei" by J. C. Peng and J. E. Simmons, Los Alamos, spokesmen.

Participants:
Los Alamos: T. A. Carey, D. H. Fitzgerald, J. Kapustinsky, T. K. Li, J. M. Moss, N. Stein, S. Wender

We propose to undertake exploratory inclusive measurements of eta meson production by pion beams on nuclear targets for incident beam momenta in the range 620 to 700 MeV/c. A simple BGO counter system will be used for the detection of energetic gamma rays from η to 2γ decay. For one target, ^{12}C, a momentum excitation curve and an angular distribution will be measured. At a fixed momentum, $\approx$ 700 MeV/c, the dependence on target mass will be measured for CD_2, carbon, aluminum, titanium, nickel, and germanium.

#935 "The Development of a Source of Ultra-Cold Neutrons at the Line E Beamdump" by J. D. Moses, Los Alamos and G. R. Ringo, Argonne, spokesmen.

Participants:
Los Alamos: N. Jarmie, T. Dombeck
Argonne National Laboratory: M. S. Freedman
University if Missouri: S. Werner
University of Texas/AF Weapons Lab: W. Miller

Max-Planck Institute, Munich: J. Anandan

We propose to develop a source of Ultra-Cold Neutrons (UCN) using neutrons produced at the beamdump at Line E. We hope to demonstrate that the LAMPF beam, when coupled with an efficient neutron production target and moderator, is the best source currently available for the production of cold (20° K) neutrons, and that with the addition of a mechanical Doppler Shifter will produce the highest density of UCN in the world. Probably the most important experiment that could be done with such a source of neutrons is to measure, or lower the limit on the value of, the electric dipole moment (EDM) of the neutron. Our immediate aim for the next cycle is to demonstrate that such an experiment at LAMPF would be competitive with reactor-based experiments. (Other experiments of fundamental importance may be practical with this source - for example, it has been suggested that the electric polarizibility of the neutron might be measurable using UCN interferometry.)

#936 "Dosimetry Experiment to Characterize the Radiation Environment at LAMPF Target Station A-6" by D. R. Davidson, Los Alamos, spokesperson.

Participants:
Los Alamos: W. F. Sommer, R. D. Brown
Iowa State University: M. S. Wechsler

Radiation produces atomic displacements, gaseous products and transmutation products that can change the properties of materials. To understand the basic mechanism of radiation damage, the radiation impinging on the sample and the experimental equipment must be quantified. This experiment will characterize the radiation environment at the upgraded irradiation facility at the LAMPF Target Station A-6. Irradiations at the Los Alamos spallation radiation effects facility will be possible in the direct proton beam and in the spallation neutron flux resulting from the interaction of the primary proton beam with the Isotope Production targets (IP) and the beam stop. The dosimetry experiment will include 1) measurement of the flux and spectrum in the proton irradiation port, 2) measurement of the flux and spectrum in the neutron irradiation port with all IP targets inserted, and 3) measurement of the flux and spectrum in the neutron irradiation port without all IP targets inserted. The measured proton and neutron fluxes and spectra will be compared to a Monte Carlo computer calculation characterizing the radiation environment at the upgraded facility.

#937 The Reactions (π,π') and $(\pi,\pi'p)$ on ^{3}He and ^{4}He at Energies Above the (3,3) Resonance" by R. C. Minehart, University of Virginia, spokesman.

Participants:
University of Virginia: C. Smith, R. Whitney
Los Alamos: P.A.M. Gram
Argonne National Laboratory: H. Jackson, J. Schiffer, B. Zeidman

Northwestern University: R. Segel

The differential cross section for the ($\pi,\pi'p$) reaction in ^{3}He and ^{4}He will be measured at energies of 350, 400, and 475 MeV at angles of 60°, 90°, and 120°. The scattered pions will be detected in the LAS spectrometer in the P^3 beam in coincidence with the protons detected in an array of scintillation counters. The impulse approximation will be used as a starting point for understanding the interaction. Simultaneous inclusive measurements at momenta in the threshold region for quasifree scattering will permit a meaningful test of a scaling law proposed by Gurvitz that is applicable to inclusive inelastic scattering of electrons, protons, and pions at large momentum transfers. In addition, measurements of elastic π^+ - ^{4}He scattering in the region of the second dip around 110° will yield a statistically reliable description of the energy dependence of that structure with good angular resolution.

#938 "Measurement of Spin Transfer Observables in the $^4\text{He}(\vec{p},\vec{p}')^4\text{He}^*$ Reaction at 500 MeV" by S. Nanda and D. Dehnhard, University of Minnesota, spokesmen.

Participants:
University of Minnesota: M. A. Franey, S. J. Seestrom-Morris
Los Alamos: K. W. Jones, J. A. McGill, J. B. McClelland, C. L. Morris

We propose to measure polarization transfer cross sections for the $^4\text{He}(\vec{p},\vec{p}')^4\text{He}^*$ reaction at the 500 MeV with $\hat{n}$- and $\hat{s}$-type beam polarizations over the excitation energy region from 18 to 40 MeV and angular range from 5° to 30°. The sensitivity of these cross sections to specific nuclear transition amplitudes will enable extraction of individual multipole strength distributions. This multipole decomposition will aid in understanding the isospin mixing of the giant resonances in ^{4}He and will test the existence of the charge symmetry-breaking force suggested by photonucleon reaction results.

#939 "Tests of a New Relativistic Impulse Approximation for Inelastic Proton Scattering at 500 MeV" by J. R. Shepard, University of Colorado and J. B. McClelland and T. A. Carey, Los Alamos, spokesmen.

Participants.
Los Alamos: K. W. Jones, J. M. Moss, L. Rees, N. Tanaka
IUCF: A. D. Bacher

We propose to use the HRS Focal Plane Polarimeter to test a new <u>relativistic</u> microscopic theory of <u>inelastic</u> nucleon-nucleus scattering by measuring select combinations of the polarization transfer observables for a few specific excitations in ^{12}C. This theory places (p,p′) and (e,e′) on a common formal footing for the first time. In it nuclear matrix elements of <u>nonlocal</u> $\vec{j}$, $\vec{\sigma}\cdot\vec{j}$, and $\vec{\sigma}\times\vec{j}$ operators appear <u>naturally</u> in the leading-order direct amplitude, whereas in the standard nonrelativistic approach such terms have traditionally only been admitted through rather inscrutable exchange effects. Such operators may play important roles in explaining, e.g., nonzero polarization-analyzing power differences. The observable-combinations to be measured are further motivated by a plane-wave reduction of this theory which reveals intimate (and for the first time well-defined) connections between (e,e′) and (p,p′) with regards to the specific nuclear structure features probed by each. Notably they imply that comparisons between mere (p,p′) cross sections and transverse form factors from (e,e′) are treacherous at best. We seek data of sufficient precision to test these relationships as well as the extent to which they are modulated by distortion effects in (p,p′). Such measurements will also provide fundamental constraints on further developments of this theory, especially as they pertain to off-shell extrapolations of the invariant N-N amplitude and variations of the ansatz for introducing relativity into (N,N′) with respect to that used for (e,e′).

#940 "Elastic Scattering of π^+ and π^- from ^{4}He at Large Angles" by D. Dehnhard, University of Minnesota and G. R. Burleson, New Mexico State University, spokesmen.

Participants:
University of Minnesota: C. L. Blilie, S. J. Seestrom-Morris, S. K. Nanda, M. A. Franey
Los Alamos: C. L. Morris, R. L. Boudrie, W. B. Cottingame
University of Texas: C. F. Moore, S. Mordechai
New Mexico State University: K. S. Dhuga, J. A. Faucett

We propose a continuation of the measurement of the differential cross sections for π^+ and π^- elastic scattering from ^{4}He. Data are to be taken at large angles for π^+ at T_π = 90, 110, 130, 150, 180, and 260 MeV and for π^- at 150, 180, and 260 MeV. Excellent data already exist for $\theta < 115^\circ$ at most of these energies. Good data in the backward angle region should eliminate ambiguities in the phase shifts extracted from the forward angle results and thus yield a complete picture of the π - ^{4}He elastic scattering process.

#941 "Muon Spin Relaxation Studies of Disordered Spin Systems" by S. A. Dodds, Rice University, R. H. Heffner, Los Alamos, and D. E. MacLaughlin, UC Riverside, spokesmen.

Participants:
Los Alamos: D. W. Cooke, R. L. Hutson
Rice University: G. A. Gist

The proposed work will extend previous LAMPF μSR studies of disordered spin systems (metallic spin glasses and random ferromagnets) to metallic and insulating systems exhibiting single-ion anisotropy and various types of disorder, viz., random anisotropy, competing anisotropy, and random fields. Magnetic ions exhibiting Ising-, XY-, and Heisenberg-like behavior will be employed. A major goal of these experiments will be to elucidate the effects on dynamics of spin dimensionality and disorder. It will be of great interest to know if the excess of low-frequency excitations, the power-law decay of the spin correlation function, and the broadened critical width observed by our group in metallic spin glasses persist in the new materials.

#942 "Measurement of Low Energy Cross Sections for the $^{12}C(\pi^{\pm},\pi N)^{11}C$ Reactions" by M. J. Leitch and B. J. Dropesky, Los Alamos, spokesmen.

Participants:
Los Alamos: A. Cui, D. Fitzgerald, G. C Giesler, J. A. McGill, C. J. Orth, L. E. Ussery

We propose to remeasure the cross sections for the beam monitor reactions $^{12}C(\pi^{\pm},\pi N)^{11}C$ (20.33 min) over the low-energy range 20-50 MeV employing the purest pion beam we can achieve with the "Five Foot" particle separator on the LEP channel. The objective is to establish the most accurate values we can for these cross sections, which are used to put many types of instrumental and activation measurements of pion interactions on an absolute basis. Numerous counter techniques will be employed to determine accurately the number of pions that pass through a plastic scintillator target during a 40-min irradiation at each pion energy. The induced ^{11}C activity in each target will be measured by coupling the target to a phototube and making a β-γ coincidence determination of the absolute activity.

#943 "Microstructural Evolution and Mechanical Property Changes in 316 SS Aℓ and Mo under Irradiation with Different Displacement/Helium Production Rates and Ratios" by J. Yu, IAE, China and W. F. Sommer, Los Alamos, spokesmen.

Participants:
Los Alamos: J. N. Bradbury, D. J. Farnum, D. R. Davidson, R. D. Brown

The purpose of this investigation is as follows: 1) study the mechanism of bubble nucleation (heterogeneous, or homogeneous), BSD (Bubble Size Distribution) dependence on $K\alpha/Kd$($K\alpha$ - He production rate), (Kd displacement rate) and its influence on tensile properties as observed by TEM and SEM and deduced from tensile tests of irradiated single crystal samples; 2) study the importance of the grain boundary in bubble nucleation and growth and the $K\alpha/Kd$ ratio influence on bubble distribution and the resulting effect on tensile properties; 3) study the role of hydrogen and helium in irradiated 20% cold worked 316 SS and the attendant influence on tensile properties by the relationship between bubble distribution, tensile properties, and $K\alpha/Kd$; and 4) study the possibility of simulation techniques of radiation damage in the bulk of fusion first wall materials by the analysis of the dependence on microstructural evolution and property changes on Kα/Kd.

#944 "Feasibility Study for an Experiment to Search for Muonium→Antimuonium Conversion" by V. W. Hughes, Yale, J. R. Kane, College of William and Mary, and C. Hoffman, Los Alamos, spokesmen.

We propose a feasibility study for an experiment to search for muonium→antimuonium conversion using a low-energy beam of muonium atoms in vacuum and the LAMPF crystal box detector. The ultimate aim of an experiment would be to measure the coupling constant to the level of the Fermi coupling constant G_F or better.

#945 "DCX on Nickel" by K. S. Dhuga, New Mexico State University, R. Gilman, University of Pennsylvania, and C. F. Moore, University of Texas, spokesmen.

Participants:
Los Alamos: C. L. Morris
New Mexico State University: G. R. Burleson, J. Faucett
University of Pennsylvania: H. T. Fortune, J. Zumbro
University of Texas: S. Mordechai

The main interest in this proposal is to measure an excitation function on ^{58}Ni, the heaviest T = 1 nucleus. Because there is insufficient ^{58}Ni to fill the EPICS target frame, we propose to simultaneously measure DCX on ^{60}Ni. This target is chosen for two reasons. First, we have recently begun an investigation of T = 2 nuclei. An ^{56}Fe excitation function has been measured, and a ^{44}Ca proposal (906) has been approved and is expected to run during 1985. ^{60}Ni is a T = 2 target with a Q value that is about equal to that for ^{58}Ni. Second, the Q values for the two analog reactions will differ by Coulomb energy differences. The only important term for this difference is proportional to $Z/A^{1/3}$, and the difference is less than 200 keV between even-even Ni isotopes. We will be measuring it directly.

#946 "$\pi^{\pm}$ Elastic Scattering on ^{4}He" by B. M. K. Nefkens, UCLA, spokesman.

Participants:
UCLA: S. Adrian, D. Barlow, A. D. Eochon, G. J. Kim, A. A. Mokhtari, J. A. Wightman, H. J. Ziock
Abilene Christian University: M. E. Sadler and students
George Washington University: B. L. Berman, W. J. Briscoe, M. F. Taragin and students

We propose to measure π^+ and π^- elastic scattering on ^4He using ^4He-deuterium and ^4He-hydrogen mixtures at T_π = 141, 180, 220, and 256 MeV for Θ_π = 30° to 112°. The objectives are: 1) To investigate a possible violation of charge symmetry by a comparison of $d\sigma(\pi^{+4}He)$ with $d\sigma(\pi^{-4}He)$. The beam normalization will be done via measurements of $\pi^\pm p$ elastic scattering, independent normalizations at T_π = 141 and 256 MeV will be made via $\pi^\pm$ elastic scattering on deuterium; 2) To compare the neutron and proton radii of ^4He, p^3He, and ^3H via accurate measurements of the ratios $\rho - = d\sigma(\pi^{-4}He)/d\sigma(\pi^{-3}He)$ etc. The data on the trinucleon system is obtained in a separate experiment; and 3) To check the results published by Binon et al. on $\pi^{-4}He$ elastic scattering. The data have long been used to test π-nucleus scattering models and theories. The preliminary results of a recent experiment on $\pi^{\pm 4}He$ elastic scattering at T_π = 180 MeV has generated concern regarding the validity of Binon's experiment.

#947 "Measurements of Large-Angle Pion-Deuteron Scattering" by G. R. Burleson, New Mexico State University and D. Dehnhard, University of Minnesota, spokesmen.

Participants:
New Mexico State University: K. S. Dhuga, J. A. Faucett, G. S. Kyle
University of Minnesota: D. Dehnhard, S. J. Seestrom-Morris, S. K. Nanda.
Los Alamos: R. L. Boudrie, W. B. Cottingame, S. J. Greene, C. L. Morris, N. Tanaka
University of Texas: C. F. Moore, S. Mordechai
University of Pennsylvania: J. D. Zumbro
IAE, China: Z. F. Wang

We propose to carry out a series of measurements of π^+-d differential elastic cross sections over the angular region between 115° and 180° for 6 energies between 100 and 300 MeV, using the large-angle scattering setup at EPICS. The energies would be chosen to match those for which similar data were measured recently at SIN, for angles out to 130°. The statistical and systematic errors would be comparable with those of the SIN data, 3-6% and ~5%, respectively. The results will be compared with three-body Faddeev calculations of π-d scattering and to predictions of phase-shift solutions. Because of the sensitivity of theoretical calculations and phase-shift studies to large-angle data, the results should provide useful additions to the π-d data base and provide important constraints on future theoretical studies of this process.

#948 "Pion Absorption on Quasideuterons in $^6Li(\pi^+,2p)$" by B. G. Ritchie, Arizona State University, spokesman.

Participants:
Arizona State University: J. R. Comfort
University of Maryland: N. S. Chant, P. G. Roos
University of South Carolina: G. S. Adams, G. S. Blanpied, B. M. Preedom, C. S. Whisnant
University of Virginia: R. C. Minehart

VPI and State University: M. Blecher

The absorption of positive pions on ^{6}Li will be studied using plastic scintillators at incident pion energies of 20, 50, and 80 MeV. The apparatus to be used for experiment 828 will be used with a vacuum cell holding a lithium target. Angular distributions will be obtained at angles centered on the angles appropriate for quasideuteron absorption. Energy distributions for the outgoing protons will be measured, and a missing mass resolution of better than 5 MeV should be obtained. The results obtained should provide important information on the role of quasideuteron absorption in simple nuclei, and on the effects of distortions on the outgoing protons.

#950 "Mass of the Extremely Neutron Rich ^{48}Ar" by K. K. Seth, Northwestern University, spokesman.

Participants:
Northwestern University: M. Artuso, G. Garino, B. Parker, M. Sethi, R. Soundra

^{48}Ar is perhaps the most neutron rich non-alkali nucleus which can be reached by any known techniques for populating exotic nuclei. It is proposed to measure its mass by means of the pion double charge reaction $^{48}Ca(\pi^-,\pi^+)^{48}Ar$ at EPICS, and to thus test the various theoretical models for masses of nuclei far from the valley of stability.

#951 "A Systematic Search for Narrow Dibaryons in the $\vec{p} + d \to p + X$ Reaction" by K. K. Seth and M. Artuso, Northwestern University, spokespersons.

Participants:
Northwestern University: G. Garino, B. Parker, M. Sethi, R. Soundra

No systematic searches for narrow dibaryons have ever been done in an extended region of masses. Many such dibaryons are predicted and many unconfirmed reports of sporadic "sightings" abound in the literature. It is proposed to make a systematic search for such structures in measurements of $\sigma(\theta)$ and $A_{yo}(\theta)$ as a function of the missing mass in the reaction

$$\vec{p} + d \to p + X.$$

The experiment will be done with high statistics (better than ± 1.5%) and good energy resolution, (~1 MeV) and will cover the missing mass range, 1880 < M < 2350 MeV.

#952 "Measurements of Analog DCX on ^{42}Ca and ^{26}Mg at Low Energies" by K. K. Seth, Northwestern University, spokesman.

Participants:
Northwestern University: M. Artuso, G. Garino, B. Parker, M. Sethi, R. Soundra

Study of analog double charge exchange at low pion energies has acquired special interest because of claims of sizeable contributions from six-quark bags. Other models, which have had great success at and above the (3,3) resonance, obtain large enhancements of analog DCX cross sections due to contributions of $\rho^2(r)$ dependent terms in the π-nucleus interaction and due to two particle correlations in the ground state wave functions. It is proposed to measure 15^o excitation functions and forward angular distributions for analog transitions on ^{26}Mg and ^{42}Ca targets in order to obtain new data to test predictions of these models.

#953 "Testing the Pion-Nucleus Optical Potential Via Low Energy $\pi^{\pm}$ Elastic Scattering" by M. Blecher, VPI and State University, spokesman.

Participants:
VPI and State University: B. I. Fick,D. Wright
University of South Carolina: G. S. Adams, G. S. Blanpied, B. M. Preedom, C. S. Whisnant
Los Alamos: R. L. Burman, E. Piasetzky
Arizona State University: B. G. Ritchie
Oak Ridge National Lab: F. E. Bertrand, E. E. Gross, F. E. Obenshain
Hebrew University of Jerusalem: E. Friedman

We propose to test the MSU optical potential by measuring 30 and 50 MeV $\pi^{\pm}$ elastic scattering cross sections from the self-conjugate nuclei: ^{12}C, ^{16}O, ^{40}Ca. Such targets remove uncertainties due to the isospin part of the potential and differences in neutron-proton densities. In this energy region the potential parameters are presumed known from pionic atom and 50 MeV π^+ elastic scattering data.

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